19TH ONTARIO INDUSTRIAL WASTE CONFERENCE

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PROCEEDINGS

ONTARIO

MINISTRY OF THE ENVIRONMENT

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P R E F A C E

D. S. Caverly,
Assistant Deputy Minister,
Ministry of the Environment.

Chairman,
Ontario Industrial Waste
Conference Committee.

I am pleased to present to you the Proceedings of our 1972 Ontario Industrial Waste Conference. This was our 19th Conference, and has been our most successful to date - certainly in terms of the number of delegates registered. It reflects the concern felt by all interested parties in the field of pollution control.

The Toronto location of this year's Conference was well received by delegates and did, I am sure, contribute in some measure to its success. However, I am delighted to report that we have been receiving congratulatory comments on the quality of the program presented and on the organization of the Conference. All of this would not have been possible without the very valuable participation by speakers, authors and session chairmen, to all of whom I extend the sincere thanks of the Conference Committee.

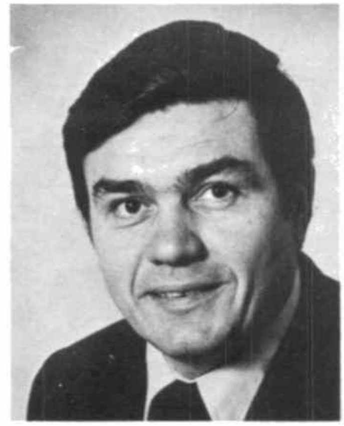
Any enquiries concerning our 1973 Conference, or enquiries on Proceedings in general, should be addressed to

the Secretary, OIW Conference Committee, Ministry of the Environment, 135 St. Clair Avenue West, Toronto 195, Ontario.

I am sure you will find the papers presented herein very useful, and a worthwhile addition to any pollution control collection. I do hope we may have the pleasure of seeing you at next year's Conference.

Conference Chairman.

SESSION CHAIRMAN,
DR. J. D. NORMAN,
PROFESSOR OF CHEMICAL ENGINEERING,
McMASTER UNIVERSITY,
HAMILTON, ONTARIO.



H. F. Hoerig

PUTTING ENVIRONMENTAL QUALITY POLICY INTO PRACTICE - DU PONT OF CANADA'S APPROACH

BY

DR. H. F. HOERIG,
VICE-PRESIDENT - RESEARCH AND DEVELOPMENT

DU PONT OF CANADA LIMITED,
MONTREAL, QUEBEC.

My assignment this morning is to outline how my Company puts its environmental policy into practice. Since no two companies are alike in organizational structure or in their environmental control requirements, it would be presumptuous to assume that our approach to the problem is the best or only one for everyone else in industry. As a member of the chemical industry, I might also add that I have become rather inured to the fact that whatever I say may be construed as only a cosmetic job by the press and public. The best I can hope to achieve, then, is that some of the concepts and ideas I put forward will be helpful to my industrial colleagues and the government representatives here today, and that more skeptical individuals will hopefully perceive that I am not talking in Elizabeth Arden terms. The time is long since past when any company could write a fine sounding EQ policy, publicize it, and forget it. Actions are more important than words, and maybe that's part of the general problem vis-à-vis the public in the environmental field.

I can recall that back in 1953, before O.W.R.C. and before "ecology" and "environment" were household words, Du Pont of Canada conducted rather elaborate tests at the construction site which is now our Maitland Works, near Brockville, to determine the biological

conditions of the St. Lawrence river bottom and determine the effect of river/dilution patterns on plant effluents. These tests involved the use of skin divers in the tracking of fluorescein dyed effluent, and a rather complicated engineering and biological control and monitoring of the entire procedure. We of course alerted our immediate neighbours along the river that the project was underway so that they would know why a part of the St. Lawrence had suddenly changed colour. Mostly we got the reaction "Why are you going to all that trouble?". While this program was progressive for the times, given the same circumstances today, undoubtedly we and O.W.R.C. would be placing greater emphasis on "in-plant" disposal of wastes rather than dilution.

In contrast to most industrial groups the chemical industry and many of the companies in it are highly diverse, with operations covering a spectrum from large chemical synthesis complexes to small operations, some largely mechanical in nature. Thus unlike the pulp and paper industry where there is a significant common denominator in technology, the chemical industry's pollution problems demand highly specialized attention varying from plant to plant. Our Company, for example, has eight manufacturing sites, each posing a different technical and economic challenge in the management of waste and the protection of the environment. This is a list (Table I Slides) of the manufacturing operations at our sites and the principal liquid wastes which require satisfactory disposition.

TABLE I

AJAX WORKS	
Paints	Caustic soda, solvents and oils
Finishes	Dissolved organics
	Suspended solids
	Paint heels
NIPISSING WORKS	
Dynamite	Organic nitrogen
Blasting Agents	Nitrates
Water Gels	Sulphates
Woven Polyolefin	
ST. CLAIR RIVER WORKS	
Polyolefin resins	Polyethylene dust and pellets
	Organic chemicals
	Phenols and dowtherm
WHITBY WORKS	
Polyolefin film	Polyethylene pellets

SHAWINIGAN WORKS

"Cellophane" Cellulose Film	Cellulose fibres Viscose Organic carbon Sulphides Sodium sulphate Sulphuric acid

MAITLAND WORKS

Hexamethylene diamine Adipic acid Tetraethyl lead "Freon" fluorocarbons "Lycra" spandex fibre "Orlon" acrylic fibre Miscellaneous chemicals	Organic compounds Nitrogen compounds Lead Oils Chlorides

KINGSTON WORKS

Nylon fibres Polyester fibres	Oil-water emulsions Dowtherm Carbon, titanium dioxide

With this impressive list of problem areas it is not surprising that the Company has long had an extensive program and investment in pollution abatement. Because of the nature of the operations, the greatest technical effort has been mounted at our Maitland Works. Here is an illustration of one problem which faced us at Maitland:

The International Joint Commission report on pollution in Lake Ontario and the International Section of the St. Lawrence River documented conditions that existed about seven years ago. Prior to this period, the discharge of partially treated waste into the fast flowing St. Lawrence was considered to have little deleterious effect on the aquatic environment.

However, the O.W.R.C. and the Company recognized that though existing regulations were being met, it was imperative to reduce the absolute quantities of organic carbon and nitrogen compounds discharged - about 6000 and 2400 tons a year, respectively. While the common objective was clear, the means of accomplishing it were obscured by the lack of industrial-scale technology. The technical challenge was to cope with or take advantage of the unique combination of these materials so that they destroyed each other to naturally occurring nitrogen and carbon dioxide.

The selection of a process which would meet our EQ objectives, and at the same time give the economically required combination of capital and operating costs, involved an extensive test and evaluation

program. The OWRC understood the dimensions of our problem and we are grateful for their understanding and co-operation while this phase of the work was in progress.

To solve our problem of carbon and nitrogen wastes, high temperature destruction was studied for about six months on a small research-scale pilot plant. Essentially the oxidizing power of nitrates in the waste was utilized to destroy the organic material - a neat chemical solution. The complicating factor in this approach proved to be the vapour pressure of water. At the high temperatures required for 90% removal it was necessary to operate a continuous process reactor in the range of 200 atmospheres pressure to keep the aqueous waste stream in the liquid state. As we were dealing with a volume of waste in the neighbourhood of 1,800 U.S. gallons a minute, the design of the equipment, including massive heat exchangers, presented a formidable engineering problem.

The competing alternative, a biological treatment scheme, was studied simultaneously. Following exploratory bench-scale tests, a five-gallon-per-minute pilot plant and a lagoon were operated for a year to evaluate operating parameters, including the effect of seasonal temperature variation on performance. In our first approach, an anaerobic denitrification step preceded carbon removal by extended aeration. However, the denitrification stage was difficult to operate because of the slow rate of bacteria growth, sensitivity to toxic conditions and low temperatures. The problem of poor sludge growth was finally surmounted by the discovery that the strain of sludge bacteria were facultative, readily adapting to either anaerobic or aerobic conditions. Some interesting features of the final process to destroy nitrogen compounds and carbon compounds occurring simultaneously in an industrial waste stream, will be reported later this year in a technical paper. The final decision to install a biological plant at an estimated cost of two million dollars is expected to receive our Board of Directors' approval this month.

We have not been without crisis problems. In the nylon synthesis step at our Kingston Works a small quantity of unreacted hexamethylene diamine (HMD) is released to the air. As the plant gradually expanded over its 30-year life, the additive effect of these small discharges resulted in a blue haze around the plant under critical weather conditions. The haze received scant attention from the public and our employees until a process change caused the emission of a chemical which had a pungent popcorn-like odour. This alerted the whole community to the haze problem within 24 hours and gave us instant publicity. Even after the odour was eliminated in a crash program, it was imperative to eliminate the haze, as it was now associated with an avalanche of popcorn in the minds of the public - not to mention Works employees, management, and Air Management Branch.

The solution was to install a series of scrubbers to condense the steam and HMD discharges from the process vents, however converting an air pollution problem into a potential water pollution problem. The University of Waterloo was commissioned to determine the biodegradability of HMD in an activated sludge process. When it was learned that the HMD could be destroyed completely, and would have no deleterious effect on water treatment bacteria, permission was granted by the OWRC and the municipal authorities to put the HMD into the plant sanitary sewer system under controlled flow rates. This program involved a capital expenditure of about one-half million dollars - but, importantly, has maintained our reputation as a good corporate citizen in the community.

Our facilities for reducing air, water and soil pollution now amount to $9.6 million, representing 3½% of our operating investment. Over the next five years we are budgeting for the expenditure of an additional $4.5 million to meet our forward environmental quality objectives and foreseen government objectives.

I have indicated that Du Pont of Canada has long been concerned about pollution abatement, and that improved performance more often than not requires new technology. I hope I have not created the impression that because of this long-standing involvement we feel that the job is completely in hand. Far from it. We recognize that there must be continued gains to offset the effect of increasing industrialization and urban growth. Basic to good performance, I believe, is the formulation of a corporate environmental quality policy that will achieve consistency of action at all levels of an organization. Here is the essence of Du Pont of Canada's policy statement:

> "All Company plants must be operated in compliance with environmental control legislation and regulations, and beyond that in conformance with good community relations. Our pollution abatement efforts must receive the same continuous attention that is applied to research and product development, and to safety and fire protection. All operating personnel are responsible for seeing that this is done. A vice-president heading a corporate Environmental Control Committee will assist and advise and report progress to the President."

That may sound like being in favour of motherhood, and it could well be just that if nothing else happened. We view it as a remit to put into effect communication and action programs that involve all concerned functions within the Company. Here is how we have assigned responsibilities: (Charts 1 and 2)

Chart I

LINE RESPONSIBILITY FOR MAINTENANCE OF ENVIRONMENTAL POLICY

VICE-PRESIDENT - OPERATIONS

PRODUCT GROUP DIRECTORS

MANUFACTURING GROUP DIRECTOR

12 Product Divisions

PRODUCT RESPONSIBILITY

MANUFACTURING DIVISION (All Plants)

ENGINEERING DIVISION

OPERATIONS RESPONSIBILITY

Plans ---------------------- Projects

Control ---------------------- Audit

Employee Motivation

Community Relations

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Chart II

CORPORATE COORDINATION

VICE-PRESIDENT
CHAIRMAN: ENVIRONMENTAL CONTROL COMMITTEE

MEMBERS:
ENGINEERING DIVISION
LEGAL DIVISION
PUBLIC RELATIONS DIVISION

RESPONSIBILITIES:

- ASSEMBLE ANNUAL CORPORATE AUDIT
- ANNUAL PERFORMANCE REPORT TO PRESIDENT
- CONFORMANCE TO POLICY
  CONFORMANCE TO LEGISLATION
  FUTURE REQUIREMENTS
  INVESTMENT SUMMARY
- PLANT INSPECTIONS
- INDUSTRY AND GOVERNMENT RELATIONS

I have presented this background on our form or organization and assignment of responsibilities because the organizational framework greatly affects the perspective and involvement of employees in pollution abatement throughout the Company, principally in the following ways: -

1. It makes clear to all 5,100 employees that the Company's concern about environmental matters stems right from the President, and is rated as important as safety of operations.

2. It emphasizes that the line organization, has unequivocal responsibility for maintaining Company policy regarding environmental quality, just as it does with respect to safety.

3. It establishes the Environmental Control Committee as a functional unit with competence in technical, economic, legal and public relations aspects of pollution. It recognizes that this Committee can make objective judgements on performance vis-à-vis policy and that by virtue of the Committee members' positions within the Company, can coordinate relations with governmental bodies, industrial groups or associations and the public.

This kind of organization format seems to be working well for us, and I believe would prove useful, appropriately modified, in even a small company as the demands on management from public and government for improved pollution abatement performance continue to escalate.

The key to assessment of our performance and fixing of program priorities is a thorough annual Environmental Quality Audit covering all aspects of pollution -- water, air, soil and noise. A superficial or qualitative approach will not yield information useful for engineering analysis or for government bodies. The annual audit from each of our plants is required, therefore, to report quantitatively on all waste streams with reference to applicable government regulations and environmental agency objectives. The audit must also include a description of any spills or other incidents having a real or potential effect on the environment and describe corrective action that has been taken to prevent recurrence. The report also deals with employee motivation programs and community relations, as well as technical and capital programs underway, or forecast, to improve performance.

Because our larger plants have environmental control staffs which are normally concerned with measuring and monitoring plant streams, it is difficult to assess the incremental out-of-pocket cost incurred by the audit. In our smaller plants, assistance is given by our central Engineering unit. A rough time estimate for the personnel involved suggests an expenditure in each of our plants from $500 to $2,000, over and above routine control costs.

After assembly of all the information, the Environmental Control Committee meets with the operating management at each plant site and reviews the findings, comparing performance vis-à-vis policy and against existing and forecast government goals and regulations. In the forward look, consideration is given to the likelihood that the principle of dilution of waste streams, on which most standards are currently based, will possibly be unacceptable in the future as standards begin to relate to absolute quantities of emissions. Where criteria or standards do not exist for a waste substance an estimate based on technical knowledge derived from the literature and observation of the environment is made to classify the material. At all of our larger plants periodic biodynamic surveys have been conducted over the last fifteen years by such private agencies as T.W. Beak Consultants Limited, Queen's University and the University of Waterloo. The results of these surveys form a part of the audit.

Following the review with plant managers, headquarters operating personnel take a look at the audit. At this point, a cynic might expect that the report would undergo considerable dilution - we have found the reverse to be true, our headquarters people tend to support plant improvement proposals by suggesting that they be enlarged or speeded up. The final stage in the audit process is to present a report to the President from the Committee. This contains recommendations for action, suggests priorities and provides a perspective on developments in public relations and legislation.

We see the benefits from this annual exercise as follows: -

1. The facts on the current environmental situation at each plant site are readily at hand in the audit document. Operating management can speak with confidence that it has the facts when public statements on pollution are required or offered.

2. A firm basis for investment requirements and priorities for pollution abatement exists for inclusion in the Company's forward financial plans.

3. With the same information filed at plants, the Central Engineering Division and corporate management, a sense of responsibility for accurate reporting and elimination of incidents at the plants is promoted.

4. The environmental control officer has the facts to conduct his advisory role competently, both within the Company and in external relations with government and public bodies.

I would like to say a few words about public relations. While there is ample evidence, particularly in this province, that effective action by government agencies and a responsible attitude by a larger

and larger segment of industry is beginning to get results, we continue to lack credibility in the press and with the public generally. This is not surprising since in the field of pollution, only violations reach the headlines and editorials all too frequently dwell only on recalcitrants. Drawing its material from a rather cursory survey conducted by the C.I.C. on professional employment last year, the Financial Post escalated the data referring to "the pitiable effort all round" of the chemical industry's environmental cleanup and described the industry as "pollution intensive". The Toronto Star early this year reported increasing public concern that "nothing serious is being done about pollution, that it has become an advertising and public relations gimmick for offending industries and culpable governments". There is damm little recognition for the good work being done. Obviously speeches - including this talk - and brochures are not the answer to this problem. Performance and good community relations are. But more than this, I believe it is time to put the accent on the positive, and begin to publicly recognize exceptional performers in pollution abatement. The Canadian Chemical Producers' Association Environmental Quality Committee has studied this situation and has developed a proposal which we believe will help encourage effective industrial pollution control. Here is the proposal: -

A PROPOSAL TO HELP ENCOURAGE EFFECTIVE INDUSTRIAL POLLUTION CONTROL

> That the relevant provincial environmental agency establish an award plan to acknowledge significant achievement in pollution control at a plant site. The award would consist of a flag or pennant of suitable design (depicting by colour and symbol the three elements, earth, air and water, involved in environmental protection).
>
> Such awards have been effective, positive motivators and have been highly valued in undertakings in which recognition and morale were key factors - for example, in acknowledgement of plants which exceeded production quotas during World War II; the Industrial Accident Prevention Association pennant presented to plants maintaining a specified accident-free period; and most people are familiar with the "Elmer" flag program used to promote safety among schoolchildren.
>
> Presentation of the flag to a qualifying plant would attract favourable community and media attention, and when flown outside of the plant would serve as a continuing reminder to employees and the public of the accomplishment as well as a reminder of the synergistic role of government and industry in improving the environment.

Criteria For the Award

1. Demonstrated achievement of a negligible waste load into the air, water and soil.

2. Compliance with all existing Government regulations, and continuing vigorous programs toward further reduction of waste levels.

3. New plant design incorporating significant achievement in environmental quality control.

4. A single program resulting in a major noteworthy reduction in levels of waste to the air, water or soil. In all cases a statement explaining the reasons for and conditions of the award shall accompany its presentation.

Establishing Qualifications for the Award

Regular surveys and inspections are made by the government agencies responsible for air, water and soil pollution abatement. The Provincial Department of the Environment which has jurisdiction over these services would make the award to any plant site meeting the criteria for the award upon application by site management with adequate documentation and proof of performance. Such award and citation could be made to the plant manager by the District Engineer of the regulatory agency.

The award would be given for a two- year period, and would be subject to review by the regulatory agencies. It would in the interim be withdrawn at the request of the Provincial Department of the Environment if such action was requested.

I am hopeful that Provincial or Federal Agencies will pick up this suggestion, or something akin to it, and that the public will come to appreciate that the award is a tough one to obtain, that it represents exceptional industrial performance, and that progress is being made in the battle against pollution. It would in some measure, I think, help to restore public confidence in the environmental programs and objectives of both industry and government. Isn't it about time we let the public know we're getting on with the job?

FEDERAL GOVERNMENT ACTIVITIES IN
INDUSTRIAL POLLUTION CONTROL

K. C. Lucas

BY

K. C. LUCAS,
ASSISTANT DEPUTY MINISTER

ENVIRONMENTAL PROTECTION SERVICE,
ENVIRONMENT CANADA,
OTTAWA, ONTARIO.

I want to tell you a story about a guy who lives in Ottawa. He works in our Department - Environment Canada - and he has this eight year old son.

One day his boy asked him this. He said: "Dad, what's the environment anyway - and what's such a big deal about saving it?" Now this fellow works in, and thinks about, the environment every day of the week. And like many of us, he sometimes has difficulty finding exactly the right words. Words to communicate the urgency of the environmental crisis. But now he found himself replying - with no hesitation whatsoever: "The environment is the world we live in, son. When it's in danger, we are too."

Which is a pretty fair definition at that. And it brings up the question of whether we shouldn't always try to define environmental things in language of the common coin. Whether definitions couched in the language and concepts of specialists don't sometimes get in the way. Because, in one important sense, environmental problems are certainly not a subject for specialization. Not if we mean by that word a narrow pinpoint focussed concentration on a given aim. Such narrow focusses, such tight definitions, aren't the solution. In fact, they're part of the problem.

This isn't an abstract philosophical thing, but a real aspect of our environmental difficulties that it's very important to understand if we're going to make any real headway against them. Let me explain what I mean.

What we've developed throughout human history has been, above all, the ability to focus physical and psychological energy. We have learned to block out what we arbitrarily define as irrelevancies and give all our attention to a given target. We've done this in everything from building of automobiles to scientific research. The ability to concentrate, which carries with it the ability to break ourselves into separate specialist pieces, has paid off in a big way for western civilization. But it's been accomplished at a price. That tight focus - that concentrated effort - has been directed towards goals which have been just as narrowly defined. And there's the rub.

The manufacturer who defined goals only in terms of production quotas and to hell with pollution - he was doing what came naturally. But the goal - even from his point of view wasn't adequately defined. After all he needed a clean environment with secure life support systems just as much as anyone else. Eventually the damage to the environment would come back to him. Then there was the sanitation department planner whose narrow mandate was to get rid of the garbage of a certain seaport. He achieved this goal by towing it out to sea and contributing to ocean pollution. And the utilities planners whose only goal was generating a given amount of electricity for their regions. Protection of the atmospheric environment was not part of the defined goal. So the power was generated and the air polluted.

In all such cases the slogan that we have been following is "keep your eye on the ball". The trouble is that we weren't keeping our eyes on that other ball - the small blue one on which we live.

And it hasn't just been a matter of goals. Definition of roles is also very much involved. We've been defining ourselves in much too exclusive terms for the good of the environment. Too much emphasis on our professional identities as engineers, as public servants, as manufacturers, as educators. What we need today are good thinking heads in all these fields. Heads surmounted, however, by not just one hat but at least two. And one of those hats has got to be marked "Passenger, spaceship earth".

One bedrock aim - one overall policy - of Environment Canada has been to widen definitions in every sector of Canadian life. We believe that a revolution of definitions needs to happen not only in governments but in industry, in science, in education - everywhere.

One example of broader definitions in Canada is the way the Federal response to the environmental crisis has been organized. The new Federal Department of the Environment is really a Department of

the Canadian part of the biosphere - that slender envelope of air, water and land in which all life on this planet exists. What the Government has done is bring together, under one Departmental roof, a multitude of activities that had hitherto been going on separately. These include the management of Canada's renewable resources - fisheries, forestry, and wildlife, and activities like meteorology and oceanography.

In addition, a new organization was formed - the Environmental Protection Service. This component, which I head, is responsible for implementing the Government's environmental protection policies. It is the Department's action arm. By organizing the Department this way, the Government was simply acknowledging the reality that the environment is one. Not just air, not just water, not just trees and fish and wildlife. The environment is all these things and the threat to it takes many different forms.

The formation of Environment Canada constituted a redefinition of another kind. It is evidence that the Canadian people recognize that environmental problems cannot be defined completely in provincial or regional terms. That in many vital respects there is an urgent need to think and act as a nation.

The Environmental Protection Service has broadly defined goals. To begin with we are responsible for both prevention and cure. We are charged with implementing and enforcing - either directly or through the provinces - various countermeasures against pollution that fall within the Federal domain. It is also our job, within this jurisdiction, to maintain environmental quality in Canada after the present threat has been rolled back.

The Environmental Protection Service is also responsible for the cleaning up of Federal works and installations across the country and preventing any future environmental problems from new activities and projects. It is a housecleaning function and this particular house is a big one.

We are also responsible for coordination and planning of measures to deal with environmental emergencies.

Finally, the Environmental Protection Service is the Federal door on which Canadians in all sectors can knock. It gives focus to Canada's national environmental programs and concerns.

Before getting to a summary of the things we are doing now, let me get back for a moment to definitions. We, in Environment Canada, define our objectives in terms of the total environment. We're concerned with both environmental and economic goals.

Because of the urgency of the situation our top authority is, of course, the physical environment. We must act quickly and decisively to stop the deterioration of our vital life support systems.

But we are very clear that this is only one part of the task. The other part of the environment will have to be protected too; and we must keep this in mind in our planning. To put it simply - yes, one objective must be to protect the environment without wrecking the economy.

We are very much aware of the perils of uncontrolled exponential growth, of expansion run wild. But we do not base our approaches on the assumption that in order to survive we must go back to a primitive, non-industrial society. We want to restore balance- not create a new, equally damaging, kind of imbalance.

Having said that, let me add that we don't believe, any more than you do, that it can be business as usual. There must be some revolutionary changes in the way we define things and the way we do things. Industrial growth of the old keep-your-eye on the ball kind is not going to work any more. It is not even compatible with human survival any more. Which means, among other things, that it isn't compatible with any sanely-defined constructive industrial goals either.

But industrial growth of another kind - that we do need. Growth and advancement engineered by people who define their roles and aims in terms that include protection of our planet and our neighborhood! This kind of advancement, with its accompanying gains in science and technology, is not only desirable but essential. It offers us, we believe, our best chance of meeting all our environmental needs, including specifically the development of techniques for dealing with pollution and maximizing resources.

I said we were thinking about the total environment. And one aspect of it that we in Government think about more than most people is the political one.

Back 105 years ago when the political and constitutional blueprints for Canada were being drawn, no one was thinking environment. No one was concerned that man's puny efforts could damage our mighty resources of air and water.

So it should not come as a surprise to find that Canada's political arrangements are not what you might call environmentally oriented. Canada is a honeycomb of jurisdictions and responsibilities. The arrangements are right for a country with our diverse cultures and geography. But working within them to protect the total environment has demanded the best that we can give in terms of innovative thinking and cooperation.

I don't intend to launch into a detailed description of the distribution of responsibilities of governments in Canada. Let me just leap ahead to the bottom line. For purposes of environmental control policy the questions of jurisdiction fit into two major categories. Proprietary rights and legislative rights.

Who owns what? And who's in charge where?

If jurisdiction over environmental management were based solely on ownership of natural resources, definitions wouldn't give us much difficulty. But the provinces and the Federal Government have law-making powers that in many places overlap. One example: the provinces, because of ownership rights, have primary law-making power when it comes to inland water. So they can legislate and do legislate on things like domestic and industrial water supply, power development, irrigation, reclamation and recreation. For its part, the Federal Government is responsible for protecting and managing Canada's fisheries, both inland and coastal. And this fact, as you'll presently see, permits the Federal Government to play a useful part in controlling water pollution.

Given people of narrow vision in high places this political aspect of the environmental picture could paralyze us. Fortunately, Canadians have been flexible enough to make these arrangements work positively. The provinces have shown, through their elected representatives, that they recognize the supra-jurisdictional nature of pollution. It doesn't stop at borders. They have recognized that many aspects of the problem cannot be successfully solved except by all of Canada - and even in some cases, only by Canada working together with one or more foreign nations.

Perhaps most important, there has been a willingness by Canadians in all parts of Canada, and in all levels of government, to work together and to define environmental problems in wide and relevant terms.

We have recognized that the situation is an unprecedented one and that it calls for new responses - new ways of doing things. They require, very basically, some new ground rules for the way we work and produce.

Federally, we have passed some new laws, written specifically to meet the current and projected needs of the Canadian environment. We have also made use of some existing legislation.

At this point I would like to have you meet one established Canadian Act which has played an important part in our water pollution control. The Fisheries Act of Canada has been on the books for a century. It demonstrates that even a hundred years ago we realized that in some aspects of environmental protection it was best to act as a nation. The Act was concerned, among other things, with keeping the country safe for fish - by keeping waters unpolluted, but the Act was concerned only with what happened after the damage was done - with punitive and corrective action after the fact. There was nothing about preventing pollution. A couple of years ago,with the pollution crisis very much in everyone's mind, Parliament put new muscle into the Fisheries Act. They broadened it to permit us to move to prevent pollution of Canadian waters inhabited by fish.

Before explaining how the Fisheries Act fits into our pollution control efforts, let me define a couple of terms.

There are two basic approaches you can take, in terms of setting standards, to protect your resources - whether air or water. One approach is comprehensive resource management. It is a long-term program. The other is control of pollution at source.

What the comprehensive water management approach involves is this. You first determine just how much pollution is safe. You define a safe upper limit of pollution for the watershed you're protecting. Then you start counting the heads of the water-users - industrial and otherwise, emptying into it.

You take that safe total capacity of pollution you've decided upon. Then you split up among the industrial and other water users. If you've done your figuring right, you can allow these installations to pollute up to a fixed "safe" level without worrying about damaging the total water quality environment.

One advantage of the water management approach is that you make very efficient use of your resource. You get, economically, the maximum economic yield from the watershed. Yet you're not damaging the environment.

Well, obviously, there's a big "if" involved. In order for the resource management approach to work, it must be based on a solid body of data. You've got to know exactly how much pollution is safe. And the standards you set must be based on a consideration of _all_ the relevant factors and parameters.

We recognize that this approach is, theoretically, the optimal one. In fact, an important piece of new legislation - the Canada Water Act - has been passed to permit exactly this kind of long-range management of Canadian water resources.

But as of right now, the data on pollution is not at hand, on which to base such a policy. We don't know how much pollution is safe.

We don't have all the answers we need to implement such a policy now. But the pollution threat _is_ now - and must be tackled immediately.

Which brings us back to the Fisheries Act, and the other approach. Pollution control at source.

In this approach we do not concern ourselves with how much pollution the receiving water can safely take. We start with a recognition that we don't know and that we therefore cannot afford to take chances. So what we control is the amount of pollution in the effluent. We control pollution _at source_. In the case of water pollution, at the water's edge. In the case of air pollution, at the lip of the smokestack, or at the end of the tailpipe.

The basic theme of our regulations is concern for the total environment. Perhaps the most important single feature is the fact that they are based on best practicable technology. Which is another way of saying that we do not ask industry to do what cannot be done. They are aimed at what is possible. At the same time they are written to give a good degree of protection for the water environment. And as we get better at abatement technology, we allow for a parallel upgrading of the regulations.

We plan, under the Fisheries Act, to issue regulations covering a list of about 20 Canadian industries and industrial groups. First one up, last September, was the nation's largest industry, pulp and paper.

I think you'll be interested in some details of our modus operandi in developing these regulations. They provide a case history of what we think is the right way to get regulations written - of how to broaden definitions in both the private and public sectors for the common good.

The pulp and paper regulations operation was kicked off in the fall of 1970 by a state of the art review. This study, carried out by Federal people, concentrated on two main aspects: characteristics of the effluent of this particular industry - also a close look at the control technology we could turn to to clean it up.

When the study was completed we invited the national industry association - CPPA - and experts from several of the provincial governments to sit down around the table and help us take it from there. The industry responded quickly and positively. They sent us some of their senior key people. So did the provinces (Ontario provided two knowledgeable experts). Together these experts made up a federal/provincial/industrial task force. This task force moved forcefully ahead to construct a set of regulations that were technically practicable, economically realistic and environmentally valid.

The kind of regulations which emerged are unique. They deal, to give just one example, not in units of concentration within the receiving water but in permissible limits of discharge of given substances. They are expressed in units of quantity per unit of production. What this means is that the amount of permissible release for any one plant will reflect its own productive capacity, and the nature of its individual units. We call this the "building block approach".

Another characteristic worth dwelling upon is that the regulations distinguish between the problems of old plants and new. They recognize that older existing plants will have a tougher time getting their effluent quality up to the new permissible levels. The effluent standards are designed to recognize the limits to which technology can be applied to old plants. For new plants coming on stream, we require immediate compliance. The regulations apply to

all new plants, expansions or rebuilds at the outset. For old plants we allow individual negotiations of schedules of compliance. The schedule is tailored in each case to the old plant's ability to upgrade its operation.

The regulations are realistic in other ways. They fix a minimum effluent standard that applies from one end of Canada to the other. So that although a particular province may make stiffer regulations to take care of a local situation, the regulations will never fall below that national baseline level. So you can go ahead and be a good corporate citizen without fear of being shafted by less scrupulous competition. You don't have to be afraid that after you've spent money de-polluting, that you face the additional financial burden of unfair competition from some other guy, somewhere else, who doesn't have to comply because he's where the regulations do not apply. They apply everywhere. We have eliminated the hazards of pollution havens. And let me say in passing that we fully understand the need to eliminate pollution havens everywhere. Which is one reason Canada has made such a strong appeal for international cooperation in this field.

The next industry for which we drew up regulations was the chlor-alkali producers. We followed the same game plan and it worked very well too. Compliance is now 100 per cent in this industry. Canada is, by the way, the only country in the world which now has enforceable legislation on the books covering mercury discharge from chlor-alkali plants. Other nations have standards and limits. But they don't have the laws to enforce them.

Regulations are now being put together for some other industries - petroleum,refining, mining and food processing are the next in line.

As you can see, development of the regulations has been a cooperative, all-Canadian operation. This theme carries through to actual implementation and enforcement after they are written. Wherever possible, we want the provincial governments to undertake the administration and the enforcement roles. And in fact, in five provinces already the regulations are being enforced by provincial agencies.

The provinces, meanwhile, are developing their own regulations and standards. So one obvious question that comes up is: "Whose standards apply?" The rule of thumb is that the stiffer of the two standards will prevail. This is consistent with our two objectives - (1) to keep a good solid floor for water quality in place across the country; (2) to allow for even tougher regulations by the provinces to take care of local situations that may require it.

We're doing some other useful things to protect the water quality of Canada. One is to give leadership in the search for new ways to take the sting out of pollution. We have a special branch working on new wastewater and sludge treatment technology. We're working in this area in partnership with industry, with universities, municipalities and provincial agencies. We're doing this not only for water, but for air pollution treatment technology as well.

We've also seen some major new developments in air pollution control. When Parliament passed the Clean Air Act last year it gave us several badly needed new weapons against air pollution.

Perhaps the most important single benefit has been a new ability to build uniformity into our responses to Canada's air pollution problems.

Before the Clean Air Act, and still for that matter, there had been a great diversity both in expertise and relevant legislation among the ten provinces. Wherever this kind of unevenness prevails, there you find a potential breeding ground for pollution havens. So one fairly obvious national need was to set up national air quality objectives - targets which would apply across Canada. The Act has allowed us to develop these aiming points. Objectives were proposed publicly last year for five major air pollutants. National automobile emission standards are also in place and new more stringent standards are now proposed.

We also wanted to ensure what needs to be done in this field does get done. These capabilities, these teeth, are built into the Clean Air Act. We are also able to provide some Federal leadership and coordination in important matters. For instance, we are compiling a national inventory of source emission data. We also have authority under the Act to control the composition of fuels that may be produced in Canada or imported here. Here again the approach has been to call for application of the best practicable pollution abatement methods, and to stop pollution at source. Here, too, we work hand in glove with the provinces. One of our main coordination vehicles is the Federal-Provincial Committee on Air Pollution.

We also have a new program in the field of solid waste. One of the things we are doing now is developing a comprehensive system for collecting and disseminating information on solid waste management.

We are carrying out environmental impact studies. An environmental impact study is a technical term for the question: "It looks fine economically. But what the hell is it going to do to the environment?" A question posed, not in hostility or with prejudice, but simply out of a realization that failure to ask this question is a luxury we cannot afford anymore. Along with the provinces involved, we are studying the impact of a proposed oil transshipment port at Lorneville, New Brunswick. We have mounted studies of the proposed Mackenzie Valley pipelines, the proposed refinery at Come-by-Chance, Newfoundland, and we are studying the whole question of marine oil exploration and transportation.

We're also making ourselves ready to deal with environmental accidents, including oil spills and other disasters on land and water, or in the air. To do this we have set up a special Environmental Emergency Branch. It will be seeing that contingency plans are prepared for all conceivable emergencies and developing a central operations centre in Ottawa, as well as regional operation centres to coordinate planning and response with provinces, industry and local authorities. From these centres we will quarterback the Federal response to these disasters.

Finally, we are doing all we can to build environmental concern into the balance sheets. There's a 12 per cent Federal sales tax exemption for pollution control equipment used in manufacturing processes. This is part of a growing tendency to define pollution control equipment costs as part of the normal costs of new business.

We also have the Accelerated Capital Cost Allowance - administered by Environmental Protection Service. This program's important basic aim is to make things happen quicker - to accelerate anti-pollution initiatives by industry. Under this program, equipment used primarily to abate pollution can qualify for a two-year straight line writeoff for income tax purposes. The program has been extended to include anti-pollution machinery and equipment purchased before the end of 1974.

And what about the future?

Some time ago we imposed on ourselves the discipline of setting goals for 1980. Aiming points for the future. It has been a useful exercise. By carrying it out we've been able to establish definitive checkpoints in time to navigate by. Markers which will tell us not only about the effort we have expended but the mileage we've made. Here are some of our major goals for 1980.

By that year we aim, stating it in broad terms, to have rolled back the effects of gross pollution and to have done so without sacrificing a high standard of living.

We hope to have achieved our national air quality standards. Also to have achieved a 30 per cent reduction in motor vehicle pollution. To have regulations on the books, and complied with, dealing with fuel additives and compositions.

By 1980 we aim to have compliance with minimum national effluent standards by all major water pollution sources.

We aim at instituting water management plans, including water quality and pollution abatement programs, in nine major water systems of Canada.

We aim to have our own Federal Government housecleaning complete.

We aspire to have legislation and regulations in force to control environmentally toxic substances that affect our living resources.

We plan to have a system working in which the environmental factors, pro as well as con, benefits as well as costs - routinely defined and considered in the course of decision-making about major developments, public or private.

The goals concern not only the government but the people - not only us in Environment Canada - but people in Provincial Governments and in industry.

And one goal that isn't formally stated, because it is self-evident, is that we aim to have more facts to go upon.

We need answers to questions of basic policy. Between the optimist and the pessimist who is right? Those who say we are headed for inevitable disaster regardless of our efforts, or those who say we don't have much to worry about, or those in between these extreme positions.

What about priorities? How much money should Canada spend in research on toxicology? How much on environmental impact studies? How much on monitoring systems and national inventories?

We need answers on the global problems of air pollution, ocean pollution, and the wide dispersal of certain chemicals. We need to learn more about the influence of oil spills and other man-made changes in our ecosystems. We need, to sum it up, data to fill the gaps. We need maps to steer by. We need more complete definitions.

We need, above all, a commitment to see our objectives whole. To understand that any objective whose definition does not include protection of our physical world is irrational and self-destructive. We need to think wide thoughts and wear many hats.

Thank you.

D. S. Caverly

W. A. Steggles

AGREEMENT BETWEEN CANADA AND THE UNITED STATES ON GREAT LAKES WATER QUALITY

BY

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Pollution of the Great Lakes, especially Lake Erie, has become a matter of great concern to both Canada and the United States because of the importance of the lakes as a natural resource and their key role in the lives and industry of 30 million persons.[1] The basin population is expected to become 50 million persons by the end of the century. As a result of its investigation into the condition of the lower Great Lakes, the International Joint Commission submitted its report to the governments in 1970, making twenty-two specific recommendations for joint and co-operative action.

In June 1970 Canadian ministers[2] proposed an intergovernmental agreement on pollution control in the Great Lakes, which ultimately led to the conclusion of the formal Agreement between Canada and the United States of America on Great Lakes Water Quality, signed by Prime Minister Trudeau and President

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[1]Report to IJC on the Pollution of Lake Erie, Lake Ontario and the International Section of the St. Lawrence River, September 1969, (reported basin population in 1966 was 30 million persons.)

[2]Ministers representing the Government of Canada and the Province of Ontario.

Nixon on April 15, 1972. The original proposal of the ministers resulted in the formation of a joint Canada-United States Working Group which continued with detailed review of the related technical, legal and institutional matters. In June 1971, at a second meeting of ministers and representatives of the state and provincial governments, consensus was reached on the basic principles for an international agreement; the governments announced their intention to negotiate and conclude an agreement embodying common water quality objectives, programs and other measures for achievement of the objectives, with provision for an independent evaluation of the results of the programs by the International Joint Commission.

The conclusion of these early discussions demonstrated a clear desire on the part of all the governments involved to pursue a compatible framework for future environmental quality control in the Great Lakes in implementing the recommendations of the International Joint Commission. It was recognized that the halting efforts and attitudes of the past had been insufficient, whereas a new intergovernmental team approach to the problem was required to restore water quality and cope with the growing forces of population growth and development expected in the Great Lakes Basin in future years. As a basic framework, the Agreement provides for the development of future water quality programs in a coherent and total approach to restoration and maintenance of water quality in the Great Lakes.

Water Quality Objectives

The fundamental strength of the Agreement lies in the acceptance by the governments of both general and specific objectives or conditions of water quality in the boundary waters of the Great Lakes System. Arrangements are made for modification of the objectives where the parties consider this to be necessary. Further, to avoid future degradation of water quality, the governments agreed to take all reasonable and practicable measures to maintain the existing levels of water quality where present levels of water quality exceed the water quality objectives.

Program Commitments to Achieve the Objectives

The Agreement provides that the standards and regulatory requirements of the governments will be consistent with the achievement of the water quality objectives. The agreed program commitments include: installation of phosphorus removal facilities at municipal sewage treatment plants and reduction of phosphate loadings by sewage treatment and detergent phosphate controls according to an agreed schedule of reductions; waste treatment facilities to meet the water quality objectives, to be in operation

by 1975 at all municipalities and industries discharging into the Great Lakes System; adoption of measures for the control of pest control products, measures for control of pollution from animal feed lots, disposal of solid wastes and nutrient control programs to reduce pollution from agricultural and other land use activities; maintenance and further development of the Joint Contingency Plan initially approved in June 1971 to deal with spills of oil and other hazardous polluting substances; adoption of regulations governing the discharge of wastes from vessels, and the undertaking of studies and programs to prevent spills from shipping accidents and off-shore and on-shore facilities; review of dredging operations to avoid environmental damage; and through the International Joint Commission, co-ordination of pollution studies of Lake Huron and Lake Superior and making recommendations to prevent their further deterioration and reduction of water pollution from land drainage, forestry and agricultural sources.

International Joint Commission

In recognition of the need for independent monitoring of the implementation of the Agreement, Canada and the United States proposed the assignment of new functions and responsibilities to the International Joint Commission, which include the co-ordination and independent verification of monitoring and surveillance activities reported by operating agencies, collation and analysis of data relating to the programs, tendering advice and recommendations, co-ordination of research and the independent publication of reports concerning the implementation of the Agreement.

The Commission will evaluate and over-view the operation and effectiveness of programs to protect water quality in the lakes. It will report to the governments at least annually, making recommendations for improvements in water quality objectives, programs, measures, legislation, and intergovernmental agreements relating to the quality of the Great Lakes. The governments will supply information and data to the IJC and have agreed to consult on modification of water quality objectives and improvements in programs and joint measures. When special pollution problems arise, the governments have agreed to notify and consult one another regarding the appropriate action to be taken.

Financing and Enforcement

The Agreement leaves financing and enforcement of the many pollution control programs in each country to the respective federal, state and provincial governments which have unanimously indicated commitment to achievement of the water quality objectives.

In United States terms, the Agreement is an "Executive Agreement" rather than a "Treaty", and thus does not require Senate approval. As such, United States obligations are subject to the appropriation of funds in accordance with its constitutional procedures. Nevertheless the Agreement commits the United States Administration to seek the appropriation of the funds required to implement the Agreement, and to seek enactment of any additional legislation needed to implement programs and measures under it.

In Canada the federal government and the Government of Ontario, by an Agreement signed in Toronto on August 13, 1971, have pledged funds for programs designed to meet the water quality objectives. This Agreement provides for capital expenditures on municipal sewage works expected over the period until 1975 and also funds for further research on difficult waste treatment problems. Provision is made for financing trunk sewers and sewage treatment facilities, including modifications for the control of phosphorus discharges. Of the total funds expected to be required from the federal and provincial treasuries for municipal sewage works, \$167m. will be made available through CMHC funding, with a further \$95m. from the province. An additional \$6m. is provided for the research program on an equally shared cost basis between the two governments.

Other specific measures under way in Ontario include a strong industrial waste control program, the maintenance of an Ontario Contingency Plan for control of oil and other hazardous substances in support of the national and international Contingency Plans; the maintenance of an effective vessel waste control program, measures to control the adverse effects of dredging operations, programs for the control of pesticides, and the management of solid wastes and private sewage disposal systems. In co-operation with other governments through the IJC the Ontario Ministry of the Environment will participate in detailed studies to (a) control pollution in the Upper Lakes and (b) study and recommend ways to reduce pollution from land drainage sources.

The environmental protection field is developing rapidly with increasing possibilities for obsolescence in areas such as technology; new technology and legislative and administrative measures require that a flexible approach be taken to implementation of the Agreement. It provides for the adoption of new objectives and development of new programs and measures as these become necessary in the future. The IJC will be called upon by both governments to provide assistance and recommendations for the development of the Agreement to ensure the objectives adopted by the parties are achieved as quickly as possible. Similarly, and

probably more importantly, industry and governments, including their executive and legislative arms responsible for the setting up of environmental departments and ministries, will bear the real responsibility for determining the environmental impact of proposed actions and for vigorously carrying out the accelerated programs in both Canada and the United States.

The international Agreement gives new meaning to the Boundary Waters Treaty of 1909 and as a new venture in international co-operation is likely to become a model for environmental controls in other multi-jurisdictional situations.

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J. Alan Turner

SPRAY IRRIGATION TREATMENT OF LIQUID FOOD - PROCESSING WASTES

BY

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In processing of foods, huge amounts of waste materials are accumulated which must be disposed of without creating a public nuisance. Food processing wastes consist not only of solid materials but also of liquid effluents made up of cannery washings...cooling and blanching waters...spent lye and acid...and detergent solutions, all of which - in general - have a high bio-chemical oxygen demand, or B.O.D. For instance, it has been estimated that the liquid effluent from canning one case of peas - only - 24 tins has a B.O.D. equivalent to the domestic sewage of three persons. In one year then, the effluent from Canada's pea pack alone would be equivalent to the domestic sewage of nearly the entire population of the Country.

Up to a few years ago, the average Food Processor had for disposal of his wastes, isolated land areas or

streams with diluting capacities or even usage of city sewers.

But to-day the picture is different.

In a great many instances, liquid effluents discharged into streams with a minimum of treatment have resulted in law suits, injunctions, depressed real estate values, tempers and headaches for processors in practically every section of the country.

Where city sewage disposal plants exist, they have in a great many instances, been reluctant, or have frankly refused, to handle canning plant effluents. This is because such sewage plants do not have the capacity to handle the additional load either hydraulically or organically.

The Libby, McNeill & Libby processing plant at Wallaceburg, Ontario, is located in the southern section of the Town of Wallaceburg. The plant is situated about 300 feet from the west bank of the Sydenham River. The land in the vicinity of the plant is generally very flat, and the river has a flat gradient which makes it very sluggish. The plant carries out its processing operations for about eleven months a year. From June to November, various fresh vegetables are processed as they are harvested. These include peas, red beets, corn, lima beans, pumpkin, carrots, and mixed vegetables. During the other months of the year, Libby produces a wheat product sold as either spaghetti or as small character-shaped objects called Alpha-Getti.

Please note, that although each product's waste effluent has its own characteristics, the effluent becomes more complex in nature when several kinds of crops are processed at the same time. During the peak vegetable processing season, the plant operates for seven days a week on two ten-hour processing shifts per day and one four-hour shift for clean-up purposes.

All the wastes derived from the vegetable processing operations are essentially organic in nature with very high B.O.D.'s and suspended solids content and low pH's. The spaghetti processing operation wastes are much less significant in relation to the vegetable flows.

In order to obtain more positive information on the flows and the characteristics of the wastes from the vegetable processing operation, we carried out an extensive year-long program of sampling and analyses, together with waste flow measurements. From this data - coupled with

plant production figures - it was agreed that a waste treatment facility was required in the order of 450,000 IGPD with a total daily B.O.D. loading of 9,000 lbs. Based on a 10-year increase of 3 percent per year, the flow would be in the order of 600,000 IGPD with a total daily load of 12,000 lbs... or equal to the load from a city with an equivalent population of about 70,000 persons.

Prior to 1970, through the use of in-plant gutters and drains, the processing waste waters were collected in a wet well located outside the plant building. The waste from this sump was pumped to two 20-mesh Link Belt vibrating screens in order to remove the screenable material. Spent water was discharged to the river and the screenings disposed of at a land fill site.

Other than removing coarse solids, screening alone was not giving appreciable treatment to the wastes. After screening, the B.O.D. content of the waste was still very high and the screened wastes were still unsuitable for direct discharge to the river. Besides this problem in discharging the screened wastes to the river we also had to consider the problem of discoloration, from processing red beets.

The wastes are essentially organic in nature, so they are amenable to various biological treatment processes provided that some correction of the pH is carried out on some of the wastes. Initial investigations of possible treatment means were made of both aerobic and anaerobic biological processes. We also examined several alternate methods, and I'd like to make the following brief comments on each:

(a) the activated sludge process or one of its many modifications

- very high capital cost of the treatment work
- high operating costs
- not suitable for intermittent operation
- the process demands skilled operation

(b) biological filters or trickle filters with oxidation ditch

- high capital cost
- demands an essentially continuous operation (long start-up times can't be tolerated)
- some skilled operation

(c) aerated and algae (polishing) lagoons
    - sub soil (fine clay silt) not suitable for deep (order of 15') lagoon construction

(d) anaerobic biological process

    - final effluent not suitable for direct discharge to the river
    - demands skilled operation
    - not suitable for seasonal type operation - long start-up time required
    - high capital cost
    - requires additional pilot plant work to establish design parameters which might show the method is impractical

(e) chemical treating the wastes

    - high chemical costs
    - poor final effluent quality
    - excessive volumes of sludge produced

(f) deep well disposal (sub-surface injection)

    - requires extensive research on canning wastes
    - necessary removal of S. Solid by coagulation, sedimentation or filtration for pre-injection treatment,

and finally the treatment method we chose:

(g) Spray Irrigation

Reasons for the selection of this method of treatment -

a) Seasonal nature of the vegetable canning industry corresponds, in general, to the growing season when land and cover crops utilize the maximum amount of water. Thus, the period of maximum efficiency of the spray irrigation method of waste disposal corresponds to the period of waste production.

b) The disposal system does not demand a start-up period which is of the utmost importance when treating a seasonal waste.

c) A properly designed and operated spray irrigation disposal system as a rule satisfies the requirements of complete treatment. No effluent is produced - so it can be said that the method gives a perfect effluent. In our case however, due to the fact the land is below river level in this area of the country, it must be undertiled with the water centrally collected and lifted by pump for discharge to the river.

d) When correctly designed and operated, a spray irrigation disposal system creates no odour problems.

e) The cost of a spray irrigation disposal system compares quite favourably to a complete biological treatment system. Furthermore, in a spray irrigation disposal system, the cost of land can be recovered and the land can be used for other purposes when the treatment facility is no longer required. In fact, the land could actually be improved by spray irrigation.

f) A spray irrigation system does not require highly trained personnel in its operation.

Based on a flow of 1) 600,000 I.G.P.D., 2) a B.O.D. loading of 12,000 pounds per day, 3) water requirements for pasture grasses with a medium soil texture at .25" per day at 100% irrigation efficiency - or for our general area say 75% efficiency - the water requirement would be .33" per day if waste is applied at three-day intervals.
Waste per acre applied = 0.33 X 23,000 X 3 = 23,000 I.G/acre

Land required = $\frac{600,000 \times 3}{23,000}$ = 78 acres.

The land requirement of 100 acres covered with a suitable crop of pasture grasses is based upon the following assumptions - assumptions which have been established through irrigation practices:

a) That the application of the wastes to the land is during the summer and fall months of the year when the weather can be considered moderately warm. We did not contemplate the

application of wastes to the land during the winter and cold spring months.

b) That the pasture grasses covering the spray irrigation area will require 0.25 inches of water per day during the moderate climatic conditions at 100% irrigation efficiency.

c) That the average irrigation efficiency during the period of waste disposal was to be 75 percent.

The soil in the general area of the plant can be classified as medium texture. The ground water level is, on the average, 5 feet below the ground surface - a ground water level that is quite favourable for irrigation. Such a soil can hold more than 2 inches of water per foot of depth to its saturation. And it can receive more than 1.5 inches of water per irrigation cycle per foot of depth of soil without any appreciable runoff when applied up to the rate of 0.5 inches per hour.

We anticipated that the wastes would be applied at the rate of 1 inch per acre per day every third day, giving two days' rest between applications. The wastes so applied would be absorbed by the upper 12 inches of the soil and retained for use by the cover crop during the rest period of the soil. Because of the relatively warm atmospheric temperatures during the vegetable processing season, there would be sizeable evaporation losses from the moist soil; actually, therefore, the soil would be able to absorb much more waste than assumed.

The area of Kent County where the plant is located has extremely fertile farming land and is highly developed. Generally, the area surrounding the plant consists of many farms in the size range of 25 to 50 acres. To obtain the acreage required and avoid land pricing speculation, we decided to do it, if at all possible, through a single or a double block land purchase agreement. After extensively searching within a three mile radius, we were able to locate and successfully negotiate a tract of land considered suitable for our needs. I might add that the major drawbacks were first, that the land was approximately 1-1/2 miles from the plant and second, it was on the opposite side of the river:

- options were taken on this land consisting of 175 acres, of which 125 acres were considered usable. As insurance, a second option was taken on an additional 100 acres adjacent to this property.
- soil surveys showed the land would be very suitable for S/I but the site had the disadvantages of requiring 1) the river crossing, 2) high water tables, 3) and a tile bed collection system and pumping arrangement for discharge to the river.

Installation of the Facility

The system's cost, including land purchase, was $800,000. It was designed by Libby's engineers and Proctor & Redfern Limited, Toronto-based consulting engineers.

Two major features of this installation were unusual: it uses conventional farm irrigation equipment in its spray system and most of the complex is on the side of the river opposite the processing plant. As a result, 1-½ miles of transmission line were required to move the waste.

The overall facility incorporates four pumping stations, a new kind of screening system, a 10 million gallon impounding lagoon, surge tank to permit bypassing of the lagoon, spray irrigation equipment, drainage control ditch and a 125-acre grassy field through which processed wastes are percolated. The engineers designed the complex for an average capacity of 600,000 Imperial gallons a day with a daily BOD load of 12,000 pounds. The rated capacity of the complex is 500 U.S. gallons per minute with a peak flow capacity of 1,000 gallons per minute.

The first pumping station was part of the plant's previous waste disposal system which involved elementary screening before discharge into the Sydenham. The original three 25 h.p. Gorman-Rupp self-priming centrifugal pumps were replaced with two larger 40 h.p. Gorman-Rupp's with two-speed motors (900 r.p.m. and 1,200 r.p.m.). At the low speed, one of these pumps will deliver 500 USGPM -- the average design flow of the complex. At high speed, it will carry 1,000 USGPM -- the design peak flow. The other pump is 100 percent standby.

The screening system was renovated. The original two elevated vibrating screens had become obsolete and required a great deal of maintenance. They were replaced with a relatively new type of screen known as the Dorr-Oliver DSM Screen. This system has no movable parts. It has a screening grid of sloping stainless steel traverse bars of unique configuration. Two screens were provided, each capable of passing 500 USGPM.

The other three pumping stations are new. Number 2 is designed to move the screened waste through a 10" forcemain across the river to the spray irrigation area. The waste will flow through a 10,000 foot forcemain which crosses the river at a point which is 350 feet wide and 25 feet deep.

Polyethylene pipe made by DuPont Company was selected. An inert material, it is corrosion-resistant. It has a smooth interior surface, which reduces pumping costs. And since it is light, it requires no special bedding. Since its 40-foot lengths are fusewelded, it can be tested before positioning. It also has advantages in flexibility. Because the Sydenham is a navigable waterway, the pipe is buried below the river bed to a depth of four feet, in accordance with Department of Transport requirements.

The forcemain must carry 1,000 USGPM, giving a total dynamic head of 90 feet. To do this, a second Pumping Station was built with two vertical 60 h.p. turbine pumps, each capable of 1,000 USGMP -- so one pump can serve completely as standby. Each pump, equipped with two-speed motors, can deliver 500 USGPM when operating at the low. Room was provided in the pumping station to accommodate a chemical storage tank, chemical feed pump, pH controller and associated equipment, flow-measuring instrumentation, and automatic sampling equipment.

Across the river the impounding lagoon has an embankment slope of three to one and a berm 10 feet wide at the top. It will hold 10 million Imperial gallons -- storing waste when there is no spraying and holding the small amount of waste resulting from pasta operations during the winter.

The lagoon can be bypassed through the surge tank. The surge tank also allows pumping to the spray irrigation equipment at a constant rate, independent of the rate of inflow.

Pumping Station No. 3, which is an integral part of the surge tank, houses the pumps which deliver waste to the spray irrigation system. Two submersible pumps each capable of delivering 800 USGM against a total dynamic head of 265 feet are used. Here again, one of the pumps is on full standby.

The spray irrigation equipment consists of a solid state system, that is, fixed pipes laid on the ground, suitably valved and equipped with spray nozzles. It is fed by a main header eight inches in diameter. We made use of an existing ditch running along one side of the field by building a right-angle extension to form a drainage control ditch leading to Pumping Station No. 4.

The fourth pumping station is used to discharge the treated water into the Sydenham River. The station receives not only the treated water percolated through the ground, but rain water as well.

This station has three pumps, two of which are capable of discharging 5,000 USGPM against a total head of 17 feet, and a smaller pump capable of delivering 1,000 USGPM @ 17 feet TDH. This smaller pump is intended to handle the dry weather flow.

Mac Construction Company, Wallaceburg, carried out the contract marking a major step of the anti-pollution program, where Libby's engineers and consultants have worked in co-operation with the Ontario Water Resources Commission. Technical assistance and advice came also from Libby's plants in the United States, where somewhat similar problems have existed.

Here are the findings and results of the first year's operation. The Wallaceburg cannery operations for 1971 started January 3, when wastewater from the spaghetti pack was screened and impounded in the lagoon. All wastewater was held and subsequently irrigated in the late spring when the Reed Canary Grass cover crop on the site had become established. It had been seeded in the early fall of 1970.

The summer, fresh product pack started June 21st with the processing of peas and ended November 23rd with the processing of carrots. During this period there were 132 production days.

The Wallaceburg type of wastewater disposal system is especially unique as its success depends on four main parameters:

a) volume of water irrigated on a time-area rate

b) rainfall during the irrigation period
c) depth of the water table as determined by the Sydenham River
d) loss of water via the evapo-transpiration effect.

We did not and could not expect a complete loss of wastewater with this system because the grade of the site is below the elevation of the adjacent river and under-tiled to keep the water table at a relatively constant level.

SCREENING

Raw wastewater which was screened by two, five-foot, Dorr-Oliver, DSM, stationary screens were not satisfactory for the first year operation. Solids were too wet and the screens too difficult to keep clean, since cannery wastes contain starches, oils and vegetable waxes which coat the grid bars and blind the screens almost constantly.

Grid openings of 0.3 mm were supplied by error in place of the 1.0 mm grids ordered, which greatly impeded the flows until corrected by replacement. Both screens are at maximum capacity now and during surge flows are over capacity. Possible solutions will be discussed later in this paper.

CURRENT IRRIGATION

The site covers a gross area of 175 acres of which about 100 acres have been actually developed for irrigation. The remaining area is occupied and used for a 10 million gallon lagoon, buffer zones, ditches, etc. The field is divided into two equal areas with a 2,600' forcemain between them. There are twelve lateral lines for each area spaced at 200' intervals. These lines alternate between 800' and 1,000' in length.

Sprinklers are placed at 200' intervals - four and five to each lateral. Due to pump pressures and line friction losses, each sprinkler sprays only in a 190' diameter circle.

There are a total of 108 sprinkler heads in operation, each spraying on 28,400 square feet or 0.651 acres. The total area covered by spray is 70.3 acres. Under conditions of dry weather and maximum percolation, the spray pattern does not utilize 30 acres of the irrigation field.

Under wet conditions and saturated soil, lateral water movement would effectively utilize the entire soil area.

1971 RESULTS

The Wallaceburg system was envisioned to handle a seasonal average of 450,000 Imp. gpd. with peaks of 750,000 gpd. Initial BOD's of raw wastes, ranging between 675 and 1,790 mg/L, were expected to be reduced about 95 percent - to between 65 and 160 mg/L. Suspended solids, ranging between 50 and 1,230 mg/L were expected to be reduced about 90 percent.

After irrigation, the collected underdrainage BOD ranged between 0 and 305 mg/L with a seasonal average of 58 mg/L. Both the overall average and the peak BOD reduction were 94.7 per cent within .3% of objective.

Suspended solids were reduced from a seasonal average of 343 mg/L to 30 mg/L or 91.3 percent within 1.3% over objective.

The actual hydraulic load placed on the system averaged 678,600 gpd. for the season, with peaks of over 1.0 mgd. This volume imposed a definite overload on the land. The water table became mounded in the area and from about September 1st on it was ponded in many surface areas. Ponded conditions existed beyond the end of the season until about December 1st.

There was some surface runoff at the northwest edge of the field but there was no record of water loss or BOD level at this point and it was estimated to be a very small percentage of the total volume.

Most of the irrigated water percolated into the soil bed or was lost by evapo-transpiration. Of the total of 92 mil. gal. pumped to the fields, 35.3 million gallons were collected in the tile-ditch system and pumped to the river.

Rainfall figures for the season show that about 32 mil. gal. were imposed on the land during the period of June through November. This volume must be added to the wastewater to determine the total hydraulic load handled by the system.

During the summer period the lagoon was used to impound waste water only twice during the pea pack. This resulted in an immediate odour problem and the practice

WALLACEBURG SUMMARY

BOD_5

	TOTALS	NO. SAMP.	MG.L AVERAGE	MG/L RANGE	LBS/DAY AVERAGE	LBS/DAY RANGE
PS No. 1	109,803	100	1,098	160-5,800	7,451	1,085-39,361
PS No. 2	100,637	100	1,006	50-4,200	6,827	393-28,503
PS No. 4	5,699	99	58	0- 305	142	0- 748
Tiles	5,116	83	62	7- 510	152	17- 1,250
River Up	1,320	74	18	0- 133	-	- -
River Dn	1,138	72	16	0- 95	-	- -

SS

PS No. 1	36,367	107	340	12-1,231	2,307	81- 8,354
PS No. 2	36,721	107	343	15-1,400	2,328	102- 9,501
PS No. 4	3,061	102	30	3- 286	74	7.4- 701

VOLUME

			gal.		
PS No. 2	74,650,000	110	678,636	12,000-1,040,000	Daily Records
PS No. 4	35,300,000	144	245,139	---	Total pump time
PS No. 2	92,000,000	144	638,889	---	Total pump time

p^H

			units	
PS No. 1	--	106	7.31	5.92-9.46
PS No. 2	--	106	7.34	4.90-9.65
PS No. 4	--	97	7.90	6.80-8.34

was stopped. Prolonged ponding after September 1st resulted in a septic condition in the soil and tile field.

There was a definite odour problem during this period. We will not attempt to report on the extent or severity of any nuisance factor as it would be a subjective judgement only. The Air Management Branch did inspect the site during the period.

EFFECT ON THE SYDENHAM RIVER

The average BOD of the drainage water pumped to the river was 58 mg/L, with a range between 0 and 305 mg/L for the season. There was an average of 142 lbs. per day pumped to the river with the range between 0 and 748 lbs.

Suspended solids averaged 30 mg/L and 74 lbs. per day. Ranges were between 3 and 286 mg/L and between 7.4 and 701 lbs.

The BOD levels in the river were monitored both upstream and downstream of the outfall. There was no significant difference between the figures, and no indication of an organic demand on the receiving waters.

A biological survey of the river showed a depression of 0.5 mg/L of D.O. downstream of the discharge for two grab samples. In regard to the effect on the benthic fauna, it is entirely possible that this is related to the bottom disturbances from the construction of the forcemain across the river and the installation of the underwater outfall pipe.

Additional surveys in this reach will provide more significant and confirming conclusions for the coming year.

1972 PROPOSED IMPROVEMENTS

A review of the 1971 operations showed that the irrigation system did a remarkably good job in reducing both BOD and SS in spite of the large hydraulic overload. Irrigation acreage and equipment will be added so that the size of the current system will be about doubled. The reserve 100 acres adjacent to the present site will be developed for disposal. To protect the local township drainage schemes, the tile system to the ditches will be cut off and rerouted to a central point. Here a new lift station (PS No.5) will pump the collected under-drainage to the current ditch system.

Water meeting Ontario Water Resources Commission

objectives will be allowed to flow to PS No.4 and will be discharged to the River. Water that is too high in COD and SS will be retained in the lagoon. Collected drainage will be low in BOD and should not become an odour problem in the lagoon.

The lagoon has a surface area of about seven acres and will act as a natural oxidation pond to reduce the BOD of the impounded water. It will have a treatment capacity of about 350 pounds of BOD per day. We expect to hold a maximum of 10,000 gpd. in this system.

One additional pumping station (PS No. 6) will be built to convey polluting water from the collection ditch to the lagoon. A new dam will be constructed at the ditch angle to act as a control and sampling check point.

A second pumping station (PS No.7) will be constructed in the lagoon to convey treated water downstream of the dam for discharge to the river.

We believe that a COD assay should control the allowable discharge rather than a five-day BOD. The Wallaceburg laboratory will be equipped to do this assay and a correlating factor related to BOD will be established.

The current irrigation system will be improved by adding four more lateral lines and thirty-two more sprinklers. All sprinklers will be placed on three-foot risers to effect better evaporation of waste water.

Irrigation equipment for the 1972 improvement will be of the solid set type equal to the current equipment. It will be necessary to irrigate only one-half of the present wastewater flow on the current land area with the other half to be sprayed on the additional area.

HYDRAULIC OVERLOAD PROBLEMS

Prior to the 1971 pack season, an old municipal water main was replaced by a new larger supply line. This resulted in much greater water intake and usage in the plant and probably many cases of overusage. Preliminary studies indicate that it would be possible to reduce usage by one-third.

An intensive in-plant study on flows and water saving has been made, in an attempt to reduce the quantity of plant effluent. Reduction will result in a more efficient operation of the DSM screens. It will also result in the better efficiency of our soil bed filter system and hopefully produce a lower BOD and SS

discharge to the Sydenham River.

CONCLUSIONS

The fact that the food processing industry is becoming increasingly aware of the need to work vigorously on waste control needs and their problems is amply documented by its increased expenditures for waste treatment, disposal and utilization. In 1949, waste control costs to the canning industry as a whole amounted to about one-tenth of a cent per case of canned foods produced. In 1964, 15 years later, these costs had risen seven-fold, while to-day it is estimated that the cost to the industry for water pollution control amounts to four and one-half cents per case and is forecasted to rise still much higher.

We gratefully acknowledge the invaluable help of the technical staff of the O.W.R.C. and of our consultants in the investigation as well as the planning and completion of our waste treatment facility.

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WASTE TREATMENT AND SOLIDS RECOVERY SYSTEM FOR A FRENCH FRIED POTATO PROCESSING PLANT

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1. INTRODUCTION

Water pollution control is an important consideration for any new industry which uses a significant volume of water per unit of production. This paper describes how effective pollution control was achieved at the McCain Foods Ltd. potato processing plant at Grand Falls, N. B., which produces mainly french fried potatoes.

The paper outlines how preliminary investigations, made in the processing plant planning stages, showed that the cost of pollution control was highly influenced by the potato processing methods used.

A good approach to pollution control is to use in-plant methods and processes which result in minimum waste production, low water use through recycling and by-product recovery. These concepts were employed for the McCain Foods Plant and the following sections of the paper deal with the preliminary studies, design criteria and operating results to date.

2. PRELIMINARY STUDIES

2.1 Feasibility Study of Biological Treatment of Potato Wastewater

In August 1969, the Province of New Brunswick and McCain Foods Limited jointly announced that a new potato processing plant would be built at Grand Falls, New Brunswick and that it would have both primary and secondary waste treatment facilities to minimize pollution from the resulting effluent which would enter the St. John River. Shortly thereafter, the Province commissioned ADI Limited to review current practices in potato waste treatment and report on the possibility of utilizing biological sludge from potato waste treatment as animal feed.

During the study, field visits were made to evaluate potato waste treatment plants in the Idaho area and in Ontario and a pilot plant operating at Seabrook Farms in Prince Edward Island was also visited. There was little operating experience to draw on as there were very few potato processing plants employing secondary treatment.

An extensive literature search into potato waste treatment was also conducted and reported on. ADI Limited retained the firm of Arthur D. Little to assist in determining the feasibility of employing sterile and non-sterile yeast fermentation to produce animal feed as a by-product.

Also, a comprehensive sampling and analysis program was carried out* at the existing McCain Foods Ltd., conventional caustic peeling plant at Florenceville, N. B., with a view to establishing design criteria such as flows, unit loadings, etc., which could be applied to the proposed plant at Grand Falls.

The conclusions of the study were, in part, as follows:

(1) The use of activated sludge from biological treatment of potato wastes as animal feed was not feasible.

(2) Neither the sterile nor the non-sterile production of yeast from potato wastewater was economically feasible.

(3) The most attractive methods of biological waste treatment were complete-mix activated sludge, aerated lagoon and trickling filtration using plastic media.

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* A joint project involving ADI Limited, the New Brunswick Water Authority, the New Brunswick Research and Productivity Council and McCain Foods Ltd.

The third conclusion, given above, is expanded in the following three subsections.

2.2 Peeling

The conventional peeling process involves moving the potato through a heated caustic solution and then removing the peeling with a spray of high pressure water or steam. In the last few years, a method of peeling known as the infra red or dry lye method has been developed. This latter method has a significant effect on the properties of the plant's effluent since the peelings are not allowed to enter the main waste stream. As a result, potential BOD and solids loading may be reduced by more than 50 percent. Furthermore, water consumption is lowered appreciably (peeling water requirement reduced by 90 percent) and the peelings can be handled separately and recovered for use as animal feed.

Peeling losses range from 12 to 24 percent by weight. Therefore, in the case of a processing plant with 500 tons per day potato input, the peel waste production would be 60 to 120 tons per day assuming equal water content in both raw potatoes and peel waste.

The lye used to soak potatoes is discharged with the peelings. Therefore, in the infra red process, the lye is also withheld from the main wastewater stream which results in a wastewater having a pH roughly equal to that of the water supply. In the conventional caustic peeling process, the lye enters the wastestream along with the peelings resulting in a wastewater pH of from 10 to 12. This may require neutralization prior to biological treatment.

With conventional peeling methods, a primary clarifier is essential because of the great quantity of settleable solids present. With the infra red process it is optional. Screening is required for any peeling method to remove the larger pieces of potato which gain access to the wastestream during the processing operation.

2.3 Treatment Methods

As mentioned above, the suitable treatment methods were activated sludge, aerated lagoons and plastic media biofiltration.

It was known that the activated sludge process would produce a satisfactory effluent but its operating costs, its sensitivity generally and bulking potential with a high carbohydrate waste, the greater amount of waste sludge, and the need for a higher degree of skill for proper operation, placed this process below the others for this particular installation.

An aerated lagoon would have offered lower annual operating costs than activated sludge but there were several reasons for not using one:

(1) There was not an abundance of suitable land available for building a lagoon.

(2) There was concern over possible freezing problems with mechanical aerators.

(3) There was the question of sludge buildup on the floor which would require removal; this would be difficult and would upset normal operation during cleaning.

It was decided to proceed with high rate trickling filters using plastic media because:

(1) the annual costs were lowest for this method;

(2) they are not easily upset by shock loadings;

(3) the required operating skill is not great; and

(4) this method was being used successfully on a potato wastewater in England.

One major concern in the use of trickling filters was the possibility of freezing at ambient temperatures down to -30°F. However, previous experience with rock trickling filters in the cold prairies, and the results of the pilot plant study at Waterloo[1] indicated the potential freezing problem was not sufficiently great to preclude their use.

2.4 Final Selection

The final, basic selection was to use the infra red peeling process and biofiltration. Naturally, in the choice of peeling process, there were many factors to consider regarding its suitability for potato processing and these are not presented herein - suffice it to say that, overall, the infra red process appeared to be the best one to use.

3. INPLANT CONTROL

3.1 Fluming Water

Potatoes are hydraulically flumed from the temporary storage area to the processing area. In this process, field stones, dirt and sprouts are separated from the potatoes in rock pits and mud pits. Water from the washers is used for fluming to conserve water.

[1] Report on file at CIL, Toronto

The dirt and sprouts settle out in the mud pit which contains a conventional chain and bucket grit collector having a design capacity of 80 ft^3/hr. The grit is conveyed by flight conveyors to an elevated hopper. A truck hauls the grit away for final disposal on land 1.5 times per shift on the average.

The mud pit water supernatant is recirculated for fluming. This results in a further saving in water since only about 5 percent makeup is sewered of the 3600 USgal/ton used for fluming. The mud and rock pits and grit collector are shown in Fig. 1.

3.2 Peel Handling

The peelings are recovered in a semi dry state, i.e., only a small amount of water is added to the peelings after the peeling process. The result is a thick, pasty material with a moisture content of 85 to 90 percent (the potatoes themselves are approximately 80 percent moisture).

Concrete pumps are used to pump the peel waste from the process plant to elevated storage hoppers.

3.3 Cuttings and Trimmings

The peel waste and cuttings are handled separately and recovered as a useful by-product. The cuttings are used to manufacture potato flakes, a form of instant mashed potatoes, and the peelings can be used for animal feed. Approximately one ton of cuttings per 25 tons of raw potatoes processed is thereby transformed from screenings into flakes. The "smalls" are recovered and processed for "baby boils" and "baby roasts".

3.4 Grease Separation

A substantial amount of grease may reach the waste-stream in a french fried potato processing operation and the fryer area is normally the main one for grease losses. In this plant a Wade 5400 grease trap was installed to intercept the grease in the water from the fryer area. This 100 USgpm grease trap recovers the free floating grease which is skimmed off by hand and dumped into a barrel for final disposal of land. Actual operation has shown that only a few pounds per week reach the trap because grease losses in the fryer area are being well controlled.

4. END OF LINE TREATMENT

4.1 General Description and Cost

The pollution control system for the plant is known officially as the Waste Treatment and Solids Recovery System (WTSRS). A schematic diagram of the WTSRS is shown in Fig. 2 and a general view of the waste treatment plant is shown in Fig. 3. As shown in Fig. 2, the chip plant waste stream, which is about 15 percent of the total flow, enters the WTSRS ahead of the scalping screens. The potato chip plant, also owned by McCain Foods Ltd., is located a few hundred yards from the plant which produces french fries.

If all of the waste produced was directed to the St. John River without the benefit of in-plant controls, by-product recovery and end-of-line treatment, there would be approximately 65000 lb of BOD discharged daily when the processing plant is operating three shifts per day. The actual effluent load is 1000 lb/d which is 98.5 percent removal. Most of the removal, measured in pounds, occurs through separation of the peelings, cuttings and screenings.

The WTSRS has a nominal design capacity of 1500 USgpm. All wastewater streams are combined before flowing by gravity to the primary treatment building which houses the scalping screens, vibrating screens, vacuum filter and potato waste storage hoppers.

The wastewater is prescreened en route to the primary sump pit and then is pumped to the vibrating screens. The screenings may be minced before discharge to the elevated screenings hopper.

The screened effluent flows by gravity to a primary clarifier-thickener. The sludge underflow is either pumped directly to the peelings hopper or to a vacuum filter for further dewatering prior to discharge into the peelings hopper.

The overflow from the clarifier flows to a two-stage biofiltration plant employing interstage settling and final clarification.

Humus sludge is normally pumped to a sludge digestion and dewatering lagoon; it may also be pumped to the peelings hopper or to the primary clarifier.

The domestic waste first passes through a septic tank for solids removal before being pumped through the secondary treatment plant along with the potato wastewater.

The final effluent is discharged into the St. John River, actually the headpond of the Grand Falls hydro station.

The waste treatment system was designed, built and made operational in one year. Time was saved by having ADI Limited act as project managers as well as design engineers.

The cost of the waste treatment system is shown below:

1.	Primary treatment building-screens, pumps, hoppers, building	$300,000
2.	Primary clarifier	60,000
3.	Vacuum filter equipment	50,000
4.	Biofilters and control building - biofilters, lab, office, pumps, sumps and interstage settling	390,000
5.	Pumping for biological treatment including humus	20,000
6.	Final clarifier	60,000
7.	Lagoon	30,000
8.	Piping and valves including outfall	75,000
9.	Electrical	35,000
10.	Engineering	75,000
11.	Miscellaneous	70,000
	Total capital cost	$1,165,000

The above costs are exclusive of expenditures made on any equipment, such as the grit collector, located in the processing plant.

4.2 Preliminary Treatment

The following paragraphs provide a more detailed description of the unit operations and processes.

4.2.1 Bar Screens, Sumps and Pumps

To protect the pumps, the wastewater (including that from chip plant) passes through a 5 in. x 5 in. scalping screen upon entering the primary sump pit. This screen is equipped with projections to snag wire etc. Undesirable objects are hand picked off the screen; caught potatoes are pushed through. Also, there is a magnet, located upstream in the main wastewater channel, for catching ferrous material.

From the primary sump pit, which has a sloping floor to direct the solids into the pump suction, one of two 1500 USgpm centrifugal pumps delivers water to the vibrating screens. The pumps are float-controlled and an alternator automatically changes the lead pump to the second pump.

4.2.2 Vibrating Screens

Two, 10 mesh, Link-Belt vibrating screens, each rated at 1500 USgpm, are used for screening out large solids.

The screenings may be gravity-discharged directly to the screenings hopper or passed through a disintegrator before discharge to the hopper. The disintegrator is designed to reduce the screenings to 1/2 in. cubes. The combined screw feed conveyor, disintegrator screw feed conveyor and disintegrator are all electrically interlocked with each of the sump pumps so that they are in operation when the pumps are operating. A schematic diagram of the screens and disintegrator is shown in Fig. 4.

4.2. Primary Treatment

4.2.1 Primary Clarifier-Thickener

The screen effluent flows by gravity to a 65 ft dia, center feed, clarifier with a side wall depth of 8 ft (See Fig. 5). The design overflow rate and detention time are 650 USgpd/ft^2 and 2.2 hr respectively. The specifications called for a minimum sludge consistency of 7 percent for the thickened sludge.

The scum box is provided with an overhead infra red heater and steam heat to facilitate winter operation. The scum pit, which is located in the primary treatment building, is also equipped with a steam coil. The scum is either pumped into a barrel and disposed on land or pumped with the primary sludge to the vacuum filter.

4.2.2 Vacuum Filtration

The primary sludge is dewatered on an 8 ft x 7 ft belt-type vacuum filter which was designed to dewater 5 lb/hr·ft^2 (See Fig. 6). The cake is elevated to the peel waste hopper by progressing cavity pumps.

The primary sludge may be pumped directly to the hoppers without vacuum filtration.

4.3 Secondary Treatment

4.3.1 Biofiltration

The primary effluent flows into Sump #1 from which it is pumped to Biofilter #1. Recirculating final effluent and septic tank effluent (domestic waste) also enter Sump #1 (See Fig. 7). The biofilters are designed to remove 80 percent when the applied BOD_5 load is 10000 lb/d.

Each biofilter is filled with 32000 ft^3 of FLOCOR filter media. The dimensions are 40 ft x 40 ft x 20 ft packed depth. Both filters are equipped with a fixed-nozzle distribution system, of the type shown in Fig. 8. The design irrigation rate for both filters is 0.94 USgpm/ft^2, while the minimum and maximum are 0.5 and 2.0 USgpm/ft^2 respectively.

Effluent from Biofilter #1 enters a rectangular, interstage settling tank with a hopper bottom as shown in Fig. 9. This tank, which has a design overflow rate of 5000 USgpd/ft^2, also has compartment which serves as a sump for pumping to Biofilter #2. The hopper is equipped with a perforated, humus sludge drawoff pipe. Sludge is drawn off by a vertical centrifugal pump, equipped with a timer, and delivered to the final clarifier.

The degree of recirculation can be varied as desired for best results. The rate of final effluent recirculation can be varied from zero to 1600 USgpm approximately, depending on the setting of the automatic recirculation valve, labelled G13 in Fig. 7. The bypass valve, labelled F14 in Fig. 7, has to be partially open at all times to provide a fresh final effluent sample for the automatic sampler pump which draws from the recirculation line.

It is also possible to pump humus sludge from the final clarifier to Biofilter #1 at rates up to 230 USgpm.

Final effluent normally flows by gravity from the final clarifier into Sump #1. However, as the liquid level rises in Sump #1, due to increased flows from the process plant, the driving head decreases; at very high flow rates from the process plant there is no recirculation and a check valve prevents untreated wastewater from entering the final effluent stream. When the processing plant is not running the biofilters run on the recirculation mode to keep the bios film wet and to prevent freeze-up in cold weather.

The concrete block filter walls are extended five feet above the media to provide a windbreak. The ventilation ports (indicated with an arrow in Fig. 10) are equipped with manually operated dampers so that they may be closed in winter.

4.3.2 Final Clarifier

Effluent from Biofilter #2 flows by gravity to a 55 ft dia, rim feed clarifier equipped with sludge scrapers and a central, notched weir. The clarifier, which has 9 ft SWD, provides a nominal detention time of 1.9 hr and an overflow rate of 900 USgpd/ft^2 at 1500 USgpm.

The final clarifier is equipped with a temperature sensor which triggers an alarm in the control building when the temperature drops to a preset value, e.g., 40°F. When the low temperature alarm sounds, a solenoid valve, F10 in Fig. 7, automatically opens, allowing well water to enter Sump #1. The alarm does not sound when the processing plant is running but it does when the plant is shut down during cold weather.

The humus sludge may be pumped to (1) the sludge dewatering and digestion lagoon, (2) the primary clarifier, or (3) the peel waste hopper. It is normally pumped to the lagoon, through 2000 ft of 4 in. pipe, using piston pumps.

A schematic diagram which shows all the pumps, piping, sumps and final clarifier is shown in Fig. 11; the final clarifier is also shown in Fig. 10.

4.3.3 Sludge Digestion and Dewatering Lagoon

The lagoon has a capacity of 4 USMG, a floor area of 63000 ft^2, and a maximum operating depth of six feet. The design storage period is 100 to 300 days, not accounting for seepage, rainfall and evaporation. The maximum design solids loading is 22 lb dry solids per square foot per year.

The lagoon is equipped with three concrete inlets which are 30 in. deep and have sloping sides, as shown in Fig. 12. This is to prevent freezing of the sludge line during winter operation.

The lagoon floor is pervious to facilitate dewatering. There is provision to draw off supernatant at various levels and pump it back through the biofilters.

The supernatant will be drawn off and the sludge will be allowed to dry for one or two months in the summer when the processing plant is shut down. Dried sludge will be removed by front end loader and disposed on land.

4.3.4 Flow Measurement and Sampling

The rate of flow of final effluent discharged to the St. John River is measured by a Kennison Nozzle which is connected to an indicating and totalizing meter. This nozzle is located in the "flow nozzle manhole" as shown in Fig. 13.

An automatic sampler takes a final effluent sample in proportion to the flow. The sample is continuously pumped into the laboratory where a three-way solenoid valve directs it to waste or to a receptacle, located in a refrigerator, in accordance with the signal received from the flow meter.

5. PERFORMANCE AND OPERATING DATA

The following data evolved from the first year of operation. Normally, the processing plant operates two shifts per day (8 a.m. - midnight), Monday through Friday. However, it may be shut down for longer periods according to production requirements.

5.1 Startup Dates

The WTSRS went on line in stages. This was necessary because the new process plant was ready to begin processing before the WTSRS was finished. The grit collector, vibrating screens and biofilters went on line together at the end of March, 1971. The primary clarifier and final clarifier went on line early in June as did the vacuum filter. Thus, all components of the WTSRS were in operation in the first week of June 1971.

5.2 Mud Pit Operation

The grit collector, which is usually off 1/2 hour and on 1/4 hour, elevates approximately 1 lb of mud, stones, potatoes, water and sprouts to the mud hopper per 100 lb of washed raw potatoes.

5.3 Flow

The actual wastewater flow is approximately half of the design value of 1500 USgpm. Naturally this represents a saving and benefit in several areas, e.g., pumps and screens, while it represents a disadvantage in other areas as noted below in section 5.5.

5.4 Vibrating Screens

These screens have performed very well. However, it was necessary to make some minor changes such as adding deflectors to prevent liquid from splashing through with the screenings.

Approximately 8 lb of screenings and 25 lb of peel waste were hauled away for every 100 lb of raw potatoes processed (all wet weight basis). The disintegrator was not used because the screenings were hauled away for disposal in an abandoned gravel pit rather than used as animal feed.

5.5 Primary Clarifier Thickener

Due to the low flows, the retention time is approximately 5 hr. This is good for sedimentation but sometimes results in an increase in BOD instead of a decrease across the clarifier as a result of potato solids dissolving (See Table 1). The sludge withdrawal routine was once per shift, or daily, which also contributed to dissolution.

The pH of the liquid entering the clarifier is generally around 7 while the effluent is generally between 6 and 6.8 and is sometimes under 6 when the processing plant starts up in the morning. However, after mixing with the recirculating final effluent in Sump #1, the pH of the liquid applied to the biofilters is not far under the neutral point.

The primary sludge has a much higher consistency than expected ranging from 10 to 22 percent and is usually 17 to 18 percent. Approximately 0.9 lb of primary sludge (dry weight) was pumped from every 100 lb of raw potatoes processed (wet weight). The high solids concentration is not due to a high proportion of mud as the volatile content measured 75 to 80 percent. Pumping this sludge has caused no problems due to blockages.

The pH of the sludge is usually 4.3 to 4.5; it was measured at 3.8 after one day of storage and it did not rise above 4.5 when the sludge was drawn off continuously for 7 hr. By adding distilled water to a pulverized, peeled potato it was found that the potato initially had a pH of 6.3 and after 4 hr storage the pH was 6.15. This showed that the pH of potato sludge drops readily due to bacteriological activity; naturally, the pH drops much more quickly in the clarifier where there is an abundance of seed bacteria present from the soil washing. The primary sludge smells unpleasant but not unbearable and the odor around the vacuum filter is not objectionable.

TABLE 1 BOD DATA FOR NOVEMBER 1971 SURVEY

DATE	CLOCK TIME AT END OF SAMPLING PERIOD	5d-BOD, ppm PRIMARY INFLUENT	CLARIFIER EFFLUENT	FINAL EFFLUENT	PERCENT REMOVAL BIOLOGICAL	OVERALL
23	9 a.m.	720		78	87	89
	3 p.m.	450	470	84	82	81
	11 p.m.	900	660	148	78	84
24*	3 p.m.	275	860	39	96	73
	11 p.m.	75	330	29	91	61
25	3 p.m.	920	500	52	90	94
	11 p.m.	1020	660	100	85	90

* Chip plant only on November 24, main processing plant shut down.

TABLE 2 BIOCHEMICAL OXYGEN DEMAND - SUMMARY OF THREE SURVEYS

PERIOD	PRIMARY INFLUENT	CLARIFIER EFFLUENT	FINAL EFFLUENT	PERCENT REMOVAL PRIMARY	BIOLOGICAL	PRI.+BIOL
June 28-30 1971, 48 hr.	1605	1035	147	36	86	91
Nov. 23,25 1971	800	570	92	29	84	89
May 9-12 * 1972	1455	1095	216	25	80	85

* All values shown in this row are COD based on average of 10 composite samples; BOD are incomplete but preliminary values for the BOD removals are 32, 84 and 89% respectively.

There was absolutely no ice formation on the primary clarifier. The infra red heater and the steam heat applied to the scum box and approach ramp resulted in satisfactory winter operation of the scum removal mechanism.

5.6 Vacuum Filtration

It was necessary to use an acid resistant cloth and to add squeegees (scrapers) for cake discharge before the filter performed satisfactorily. The yield was measured at 5 $lb/hr.ft^2$ (speed setting 2.5 in a scale of 10) when the sludge consistency was 18 percent; the filter cake was 3/16 to 1/4 in. thick with 46 percent solids. It is estimated that the filter yield would be 10 to 15 $lb/hr.ft^2$ at maximum speed. The filter cake solids content was 35 percent or higher at various times throughout the year.

Both the sludge and the cake are much drier than expected at design time, i.e., 7 and 14 percent respectively. Consequently, the progressing cavity pumps are unable to pump the dry cake without adding water to increase the water content to about 80 percent. Therefore, instead of vacuum filtering, the primary sludge is normally pumped directly into the peel waste hopper. It will be necessary to install a new system for conveying the cake to the hopper when it becomes desirable to dewater the primary sludge to economize on hauling and drying costs.

5.7 Biofiltration

The filters were placed in operation in cool weather and it took about a month before a good slime had developed.

The filters operated for two months without the benefit of primary clarification. The carry over of fibres was so great that it was necessary to remove all the spray nozzles from Biofilter #1. Fortunately, this did not result in blockage of the filter media.

Originally, the biofilter pumps were equipped with strainers in the discharge line to remove any material which would clog the filter nozzles. However, it was found that 3/16 in. screens clogged too frequently with fibres, etc. even with the primary clarifier in operation. Therefore, the operators have removed these screens, preferring to clean the filter nozzles more frequently.

Winter operation is quite onerous on the biological treatment plant when the processing plant is shut down. The plant was down for three weeks from Christmas to mid January when the weather was the most adverse and the biofilters were kept in operation during this period. This was made possible by closing off the ventilation ports and releasing

hot water from the blanchers; instead of wasting all of the excess steam during plant shutdown, some was used to heat water in the blanchers and to supply steam to both clarifiers.

The outside temperature was -20 to -30°F on several days, -34°F being the coldest temperature recorded. The wind chill reached -60 to -70°F. When the process plant was down, the amount of water entering the system was 150 to 350 USgpm; the liquid applied to the filters had a temperature between 40 to 50°F and the recirculation rate was 800 to 1600 USgpm.

The wastewater temperature entering the filters was generally above 50°F, and did not exceed 64°F, when the process plant was running. During the coldest period, Dec-Feb, the liquid temperature applied to the filters ranged from 40 to 64°F. On the coldest days, the temperature drop in passing through one filter was 0 to 3°F.

In spite of the above mentioned conditions it was possible to keep the filters running all winter. Full deflector nozzles were installed along the filter walls to discourage ice formation by keeping the walls generously wetted. Ice formed on two of the eight sides of the filter walls above the media line where the wind chill effect was greatest. The maximum thickness reached was one foot but this did not really interfere with operation. Ice umbrellas tended to form around the nozzles but these were easily knocked off by hand. Some ice formed on top of the media but this problem was overcome by removing the deflectors from the nozzles.

There was some freezing of nozzles. Fibres and other material would clog the nozzles and then they would freeze. They were thawed out using a propane torch with a 40 ft hose to reach anywhere in one filter.

In summarizing the winter operation from the operators' viewpoint, it was a cold, unpleasant job working on the distribution system at times. However, the significant point is that they persevered, kept the system going and are not planning to quit before the next winter comes along! To minimize the discomfort to operators, filter towers should be roofed in or else the walls should be extended seven feet or more above the media.

As far as could be determined from the laboratory results, there was no noticeable deterioration in BOD removal efficiency during the winter months. There was no noticeable deterioration in the BOD removal efficiency following plant shutdown for two days or longer nor was there any definite change in the suspended solids concentration or the pH.

Caustic spills in the process plant were a frequent reason for concern for the operators. This resulted in the pH rising above 9 onto the biofilters on occasion; the highest pH measured was 11.1 in primary effluent and 10.0 in the final clarifier. The operators of the WTSRS are normally notified of a caustic spill. The normal procedure is to monitor it for severity and if it is severe the flow is by-passed to the river through Sump #1 until the spill has passed. Sometimes the spills are not detected and the resulting high pH wastewater has caused damage to the bios slimes which required a day or two to recover. There is an alarm and time totalizer on the above-mentioned by-pass.

The allowable and design average BOD load to the river is 2000 lb/d in summer and 4000 lb/d in winter. The actual BOD discharged hovered around 1000 lb/d with the suspended solids load being similar. In spite of high fluctuation in the quantity and strength of the waste applied to the biofilters, they were able to cope, producing removals at a satisfactory level. This is illustrated in Table 1 where it is shown how the BOD applied to the biofilters varied from 75 to 1020 ppm in one day without ill effect.

5.8 Final Clarifier and Final Effluent

During cold weather, when the processing plant was down, a layer of ice formed on the surface of the clarifier. To overcome this problem a one inch steam line was run into the final clarifier.

Foam and scum accumulate in the influent raceway of the clarifier. This is believed to be a consequence of (1) a poorly stabilized effluent from the high rate process and (2) the high grease concentration in the wastewater. Although the scum is displeasing to the eye and malodorous, it does not interfere unduly with efficiency. A cover is being made for the raceway to improve the aesthetics. A preliminary assessment indicated that humus sludge recirculation increased the froth formation.

The high grease levels may interfere with the biofilter operation, through smothering, and may also hinder settling in the final clarifier through buoyancy. The grease applied to the biofilters is in the finely divided or emulsified form. The biological action in the filters may be breaking down the emulsion with the result that the formerly emulsified grease floats in final sedimentation. An attempt is being made to locate the source of the grease with a view to eliminating it.

The clarity of the final effluent is not as good as expected; the mean suspended solids for the year (Sept. 15 to May 1, 1972) was 140 ppm while the average monthly value ranged from a low of 95 ppm in January to a high of 220 ppm in October. Settling Biofilter #2 effluent for 30 minutes in a graduated cylinder indicated that a few large particles settled quickly and many fine particles settled very slowly or not at all.

Gas bubbles were observed in the final clarifier in April 1972. Naturally this would inhibit the settling process. The procedure for humus sludge pumping at this time was daily withdrawal. The sludge withdrawal routine will be changed to maintain it in a fresher condition and, hence, inhibit septicity and gas formation. Also, a trial operation will be made to determine if humus sludge recirculation will produce a clearer final effluent and other benefits.

The pH of the final effluent remains fairly steady, ranging between 7 and 8.

The NH_3-N and phosphate concentration in the final effluent were 15 to 40 ppm and 20 to 60 ppm respectively, indicating that there apparently was no nutrient deficiency problem.

5.9 Humus Sludge Production and Handling

Since startup this sludge has been pumped exclusively to the sludge lagoon. In the summer of 1971 it was noted that the sludge dewatered well leaving only a thin, very dry cake; the quantity formed up to August, 1971 was insufficient to warrant removal but removal will be necessary in August, 1972. A field inspection on April 20, 1972 showed a sludge build up of nearly one foot in the lagoon. An unpleasant odor was emanating from the sludge lagoon; however, it apparently does not carry very far as there have not been any complaints from the public.

The daily sludge pumpage, during processing plant operation averaged 12000 USgal with a moisture content of approximately 4 percent. Up to April 1972 there had not been sufficient supernatant formation in the lagoon to warrant drawoff.

5.10 Analytical Test Data Results

Table 2 provides a summary of three comprehensive surveys conducted by the New Brunswick Water Authority using automatic sampler pumps over a two or three day period.

5.11 Overall Waste Solids Production

The overall potato waste haulage from the WTSRS was approximately 40 lb per 100 lb of raw potatoes processed (both wet weight basis). This does not include (1) the humus sludge pumped to the lagoon, (2) solids lost in the final effluent, or (3) the waste recovered from the mud and rock pits.

5.12 Operating Personnel and Costs

The WTSRS is run by five operators and one laboratory technician; this does not include the truck drivers who haul waste. These five personnel, working an average of 48 hours per week, are able to man the plant around the clock, seven days per week.

The total cost of trucking waste solids to land disposal, seven miles one way, was slightly under $1.00 per ton of material hauled.

The waste treatment plant labor cost averaged $3000 per month. The power requirement for the plant was not measured separately but 100 HP (continuous) would be more than ample for the whole treatment plant.

6. SUMMARY

This paper describes how in-plant measures, separate handling of solid wastes and end-of-line treatment were employed to meet the pollution control requirements for a potato processing plant in New Brunswick. The results of over one year of operation are discussed.

The primary clarifier-thickener produces a sludge which has a consistency of 10 to 22 percent and a pH of 4.3 to 4.5. The vacuum filter cake solids level was 35 percent or higher.

The waste treatment system, including plastic media biofilters, functioned satisfactorily during sub-zero temperatures. This was possible as a result of employing measures to guard against freezing.

The biofilters achieved 80 to 90 percent BOD removal during the first year of operation and were able to satisfactorily cope with widely fluctuating hydraulic and organic loadings and high grease concentrations.

The sludge digestion and dewatering lagoon has provided a satisfactory method of disposal of the humus sludge.

The overall potato waste haulage was approximately 40 lb per 100 lb of raw potatoes. In addition to this, 12 lb of humus sludge and 3 lb of mud and rocks were produced per 100 lb of raw potatoes processed. Finally, approximately 0.12 lb of suspended solids per 100 lb of raw potatoes escaped in the final effluent.

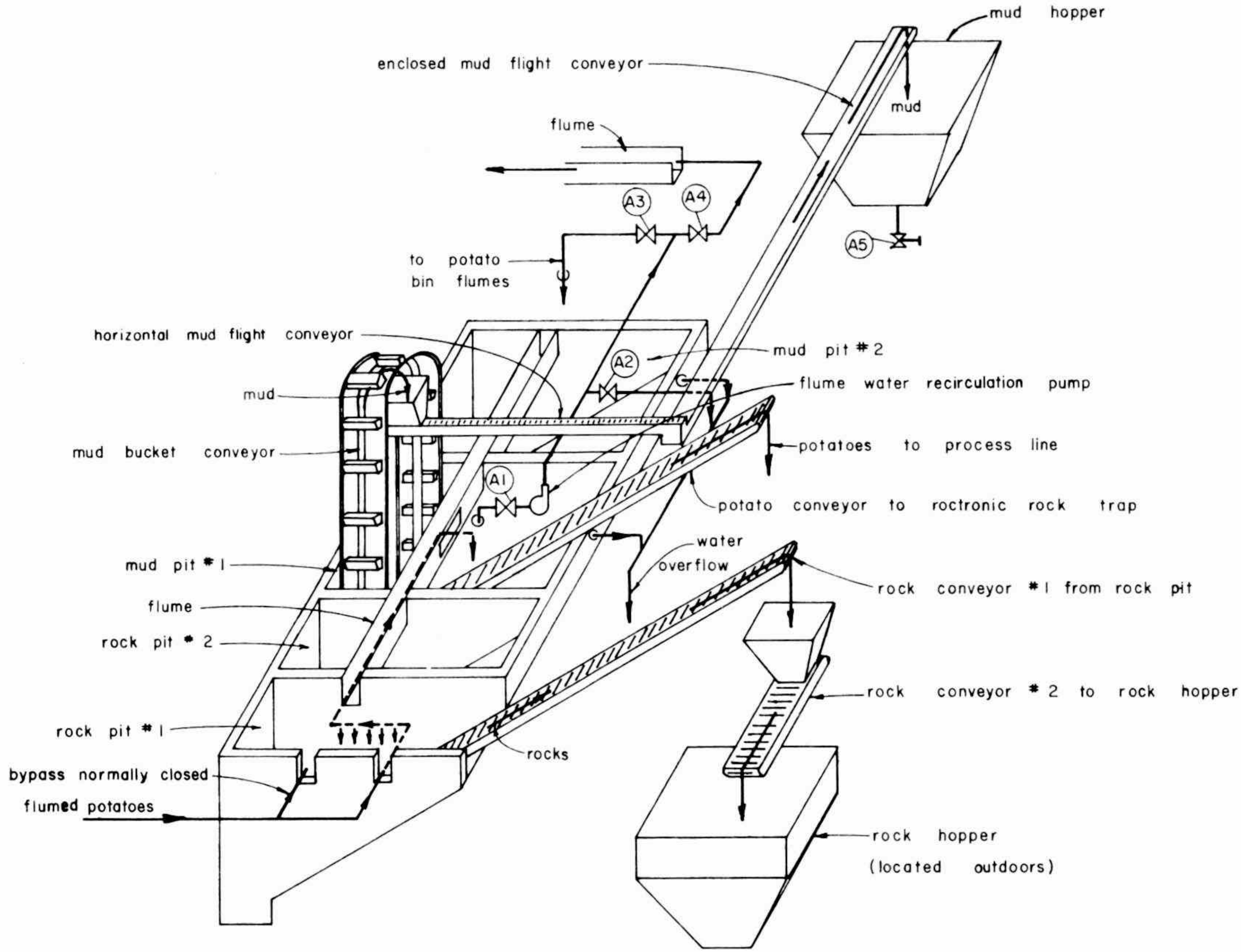

FIG. I MUD AND ROCK PITS AND GRIT COLLECTOR

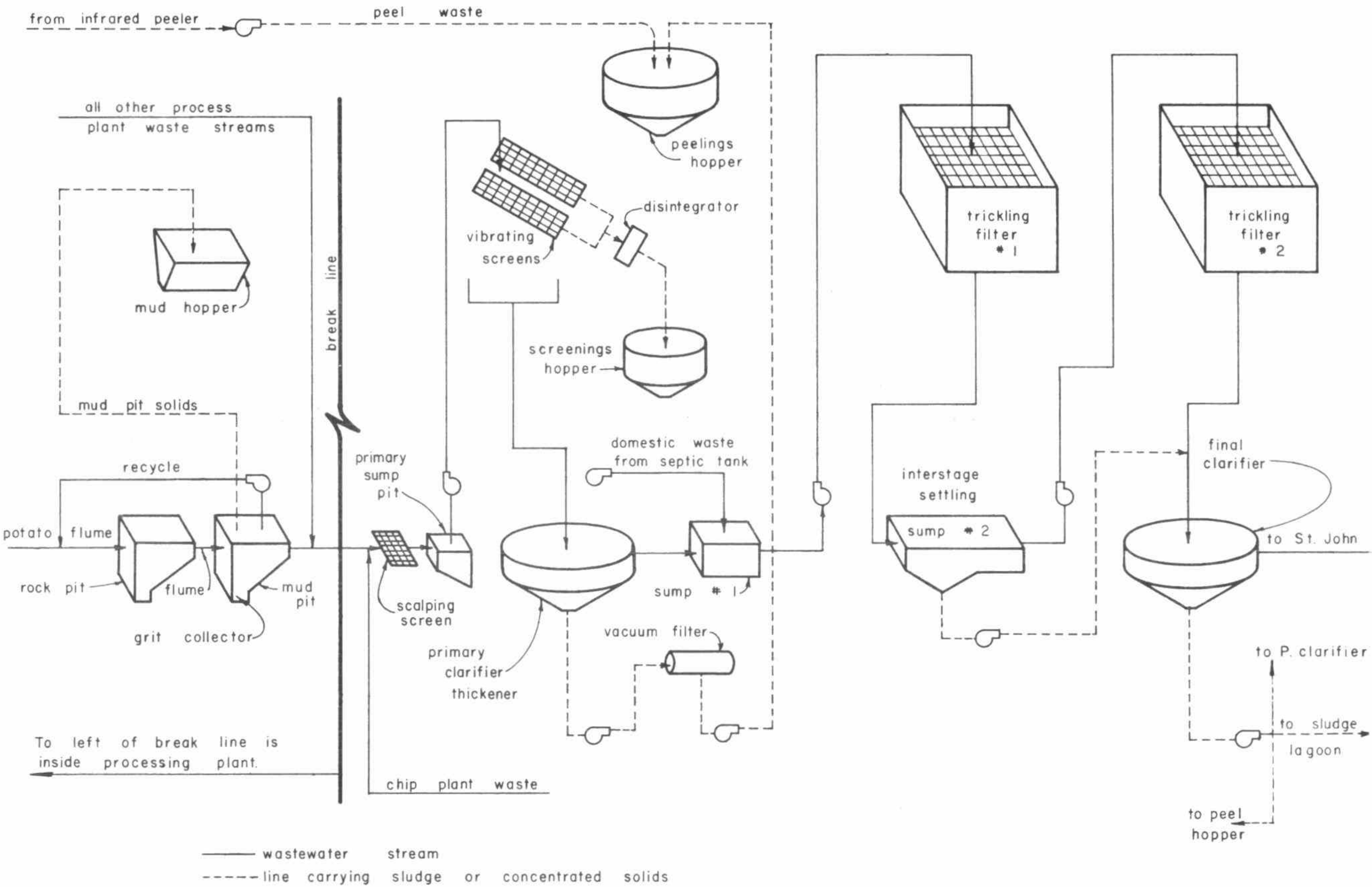

FIG. 2 SCHEMATIC DIAGRAM OF WASTE TREATMENT AND SOLIDS RECOVERY SYSTEM

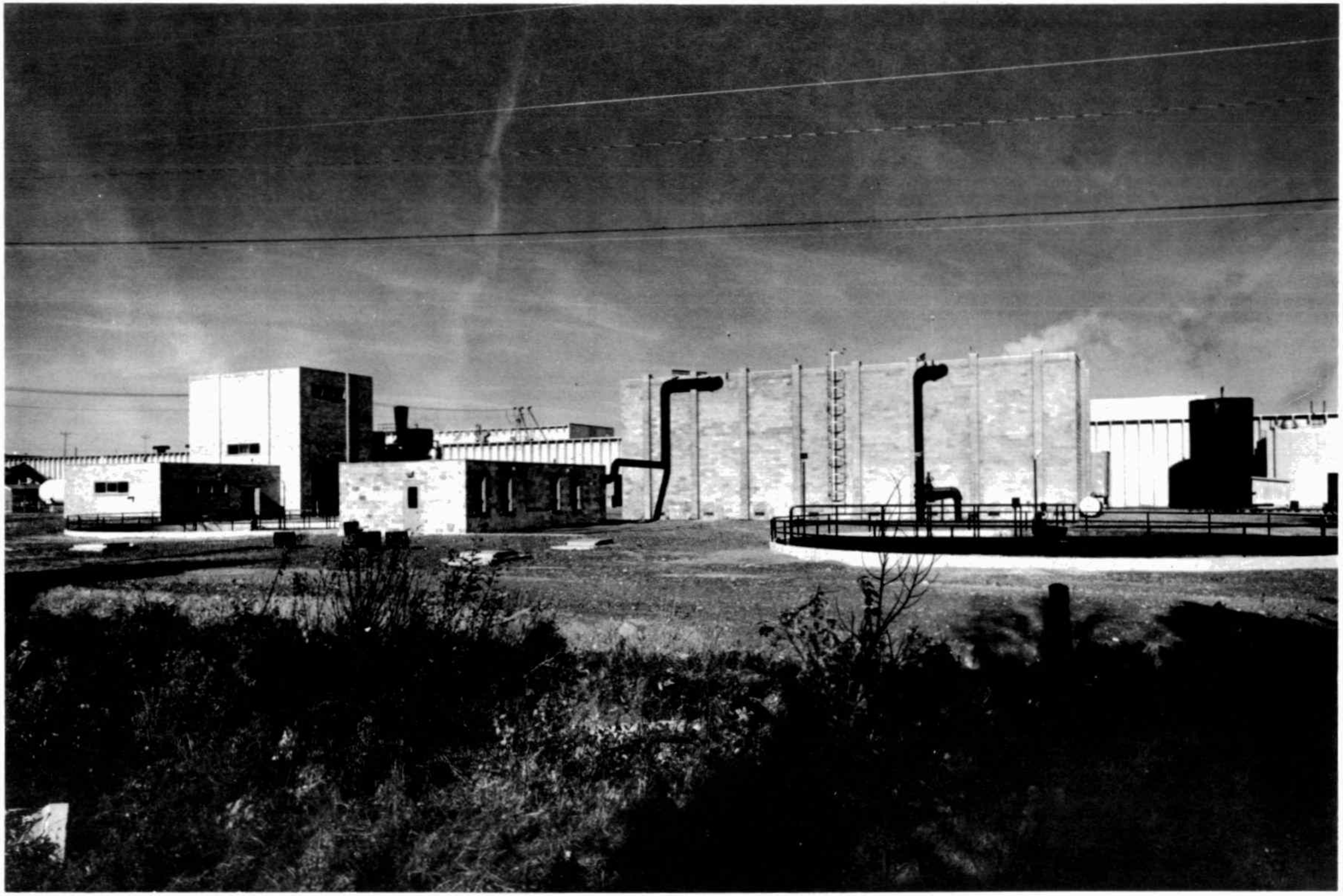

FIG. 3 GENERAL VIEW OF WASTE TREATMENT PLANT : LEFT TO RIGHT – PRIMARY TREATMENT BUILDING, PRIMARY CLARIFIER, CONTROL BUILDING, BIOFILTERS, FINAL CLARIFIER.

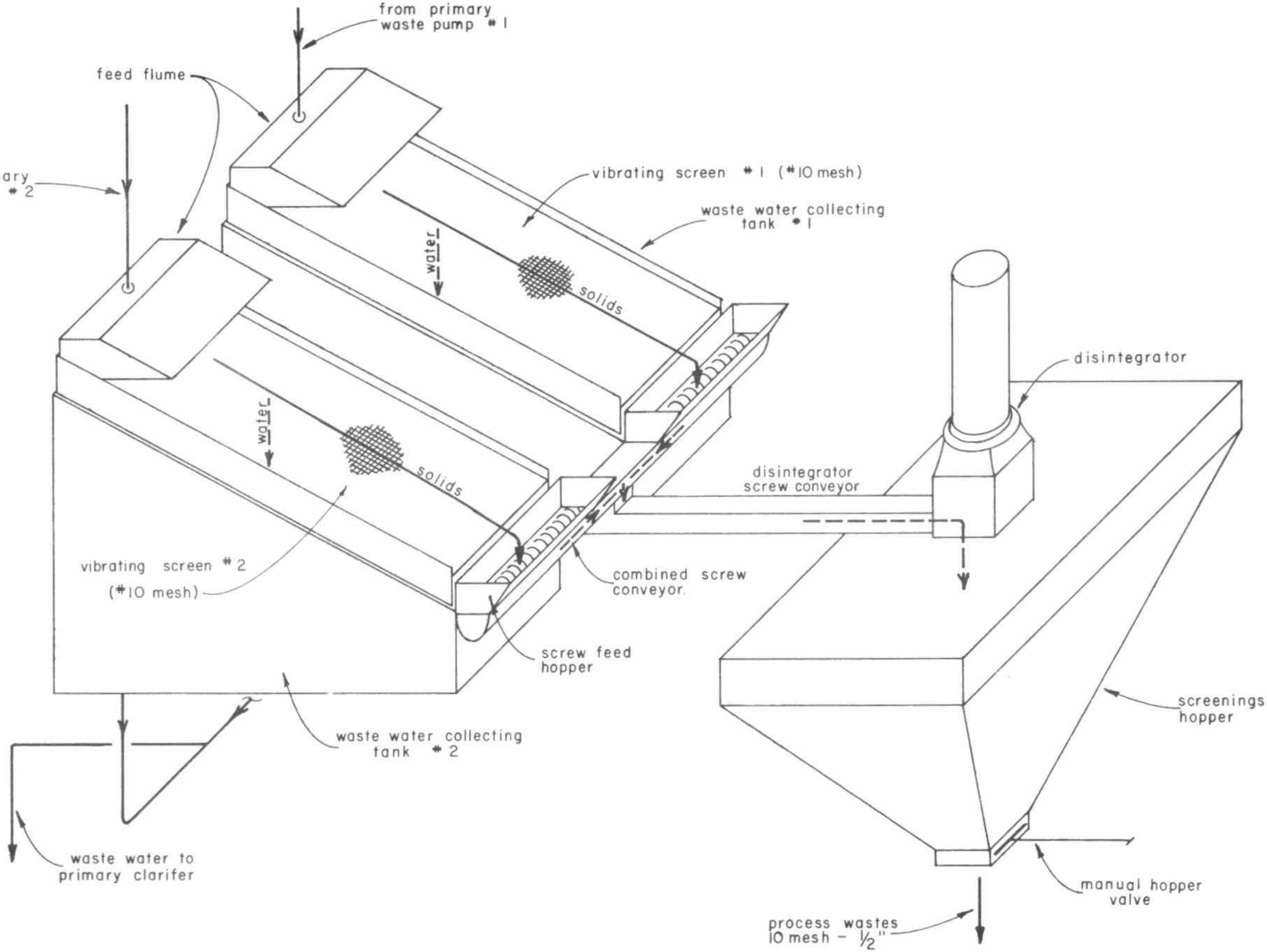

FIG. 4 SCHEMATIC OF VIBRATING SCREENS AND DISINTEGRATOR

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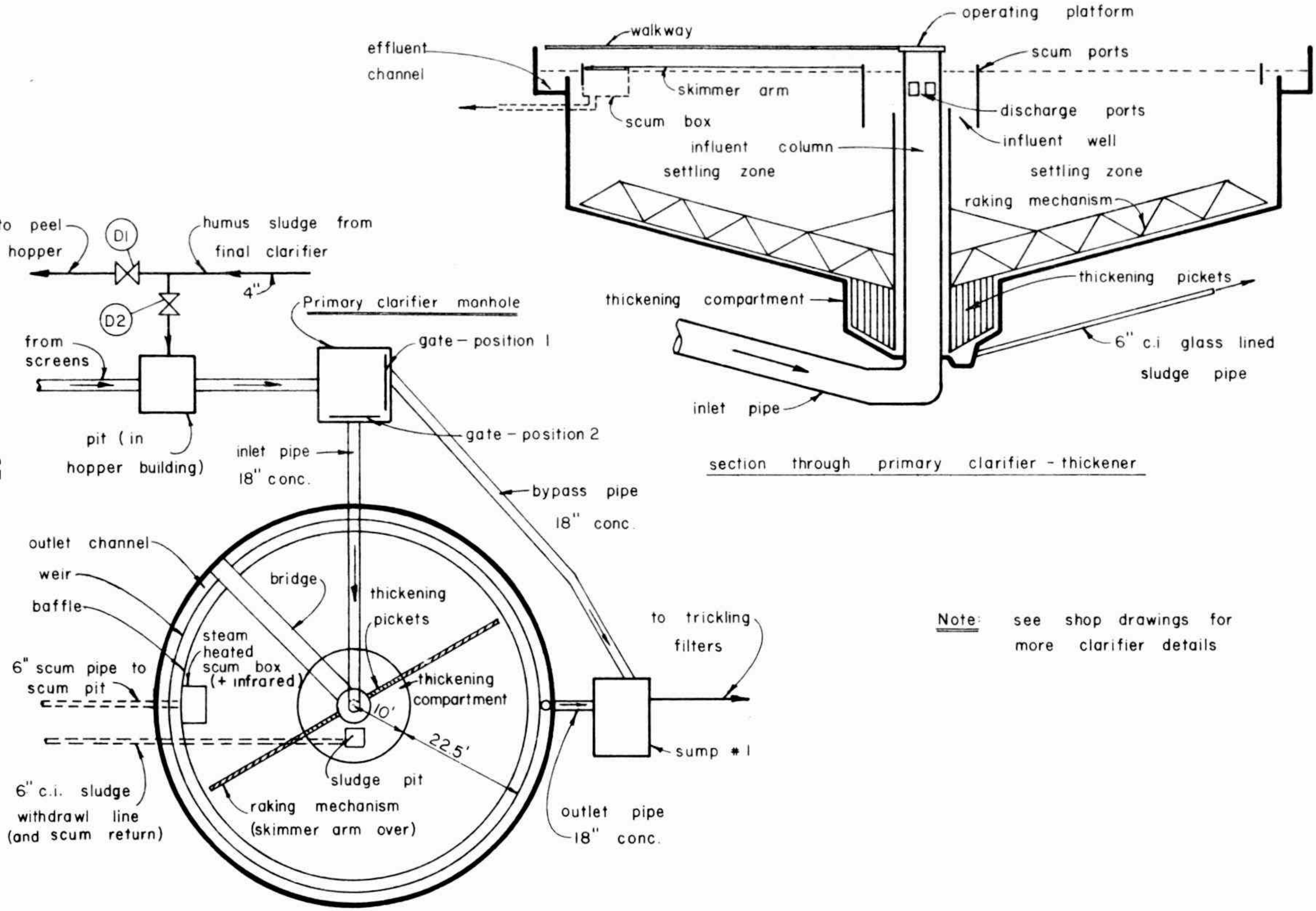

FIG. 5 PRIMARY CLARIFIER — THICKENER

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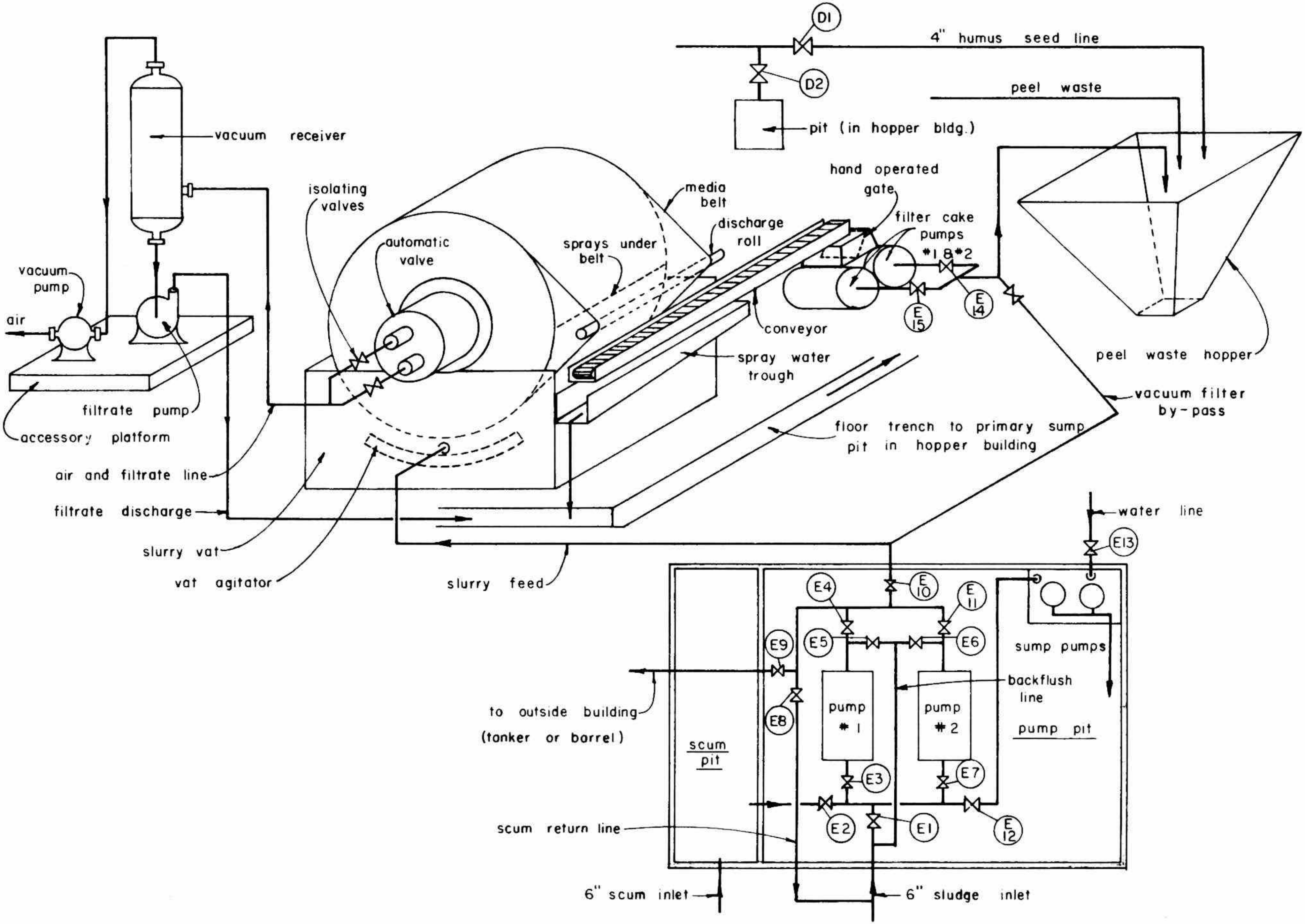

FIG. 6 VACUUM FILTRATION AND PRIMARY SLUDGE HANDLING

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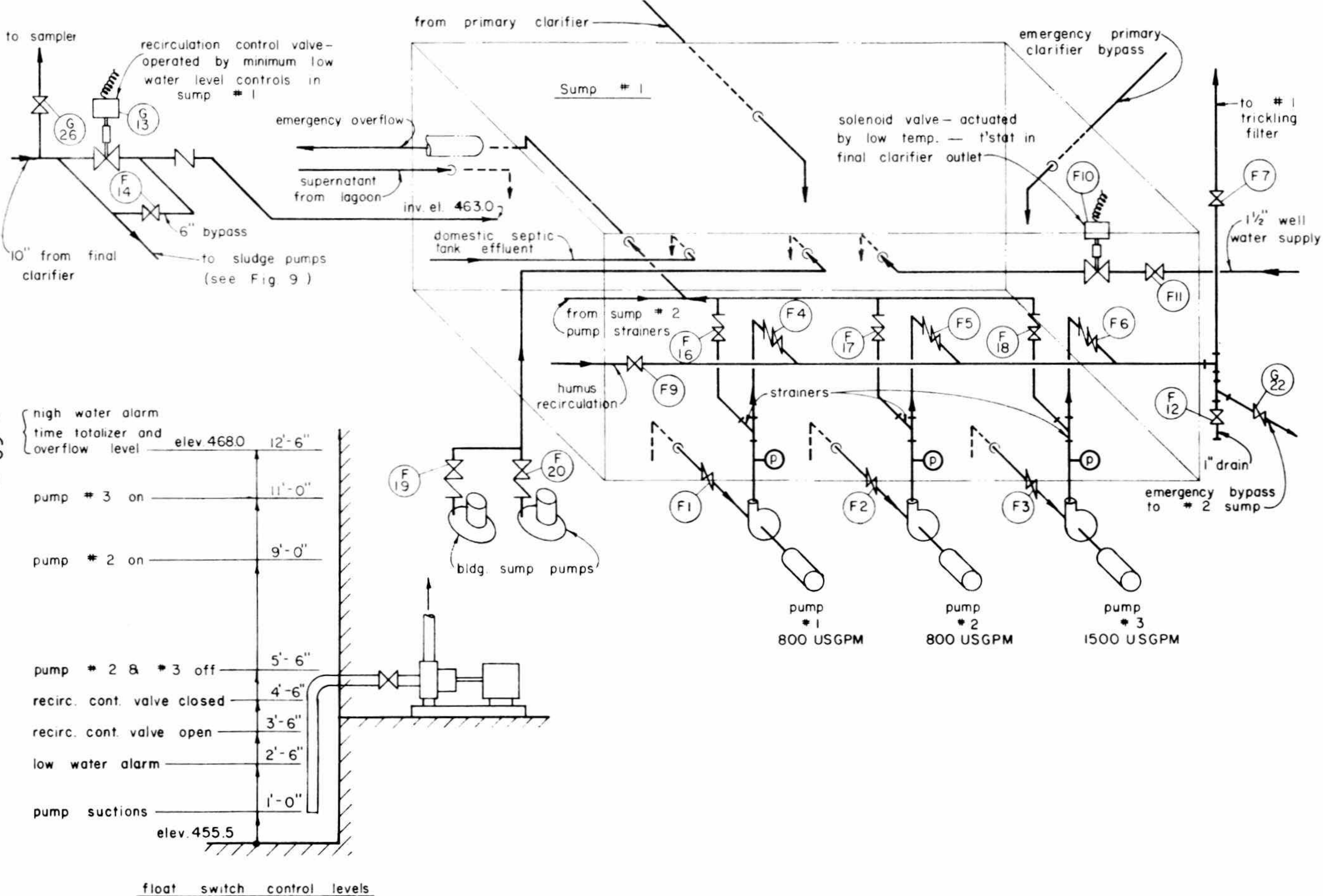

FIG. 7 SUMP # 1 AND # 1 TRICKLING FILTER PUMPS

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FIG. 8 FIXED - NOZZLE SPRAY DISTRIBUTION SYSTEM

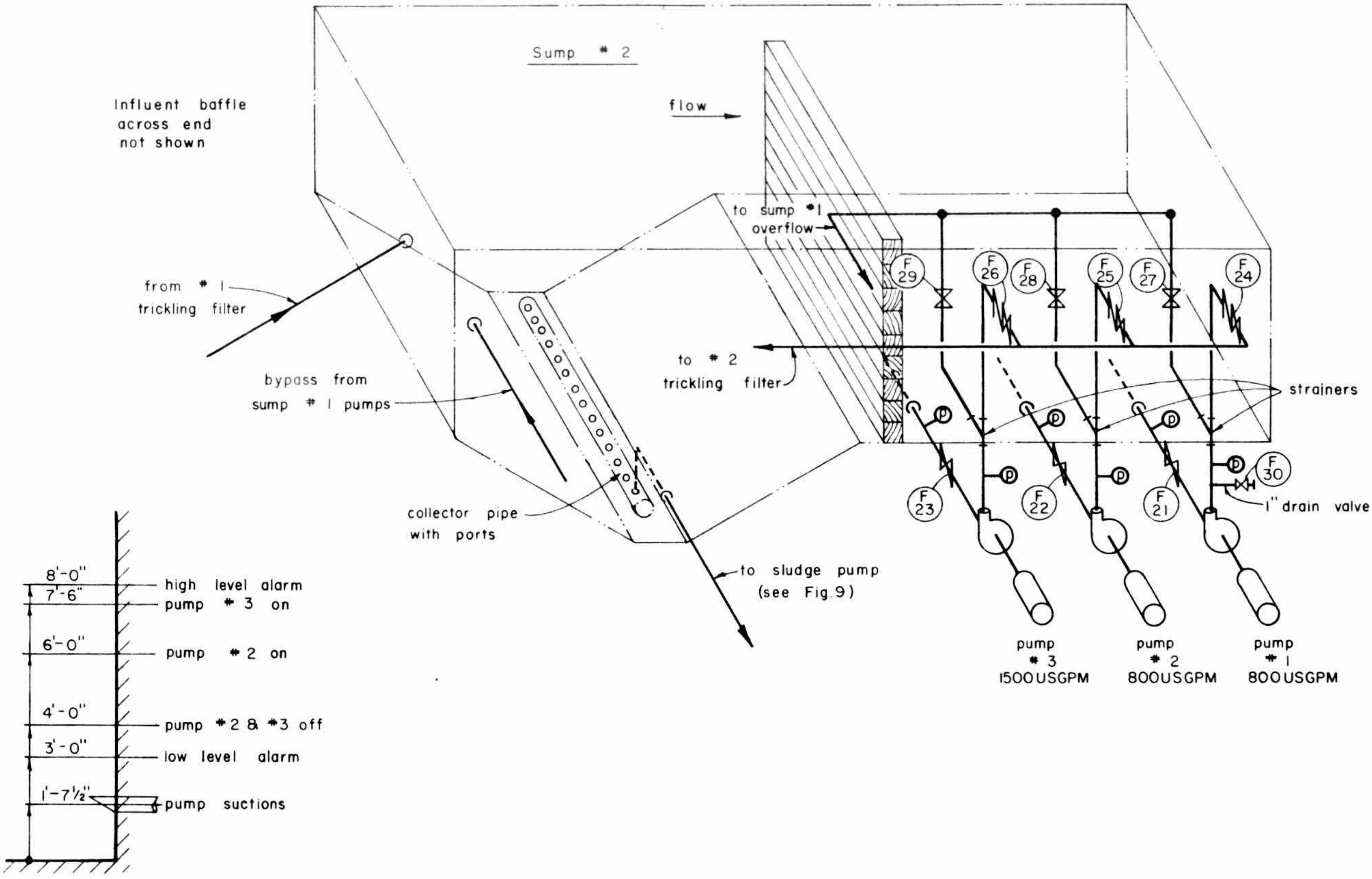

FIG. 9 SUMP # 2 AND # 2 TRICKLING FILTER PUMPS

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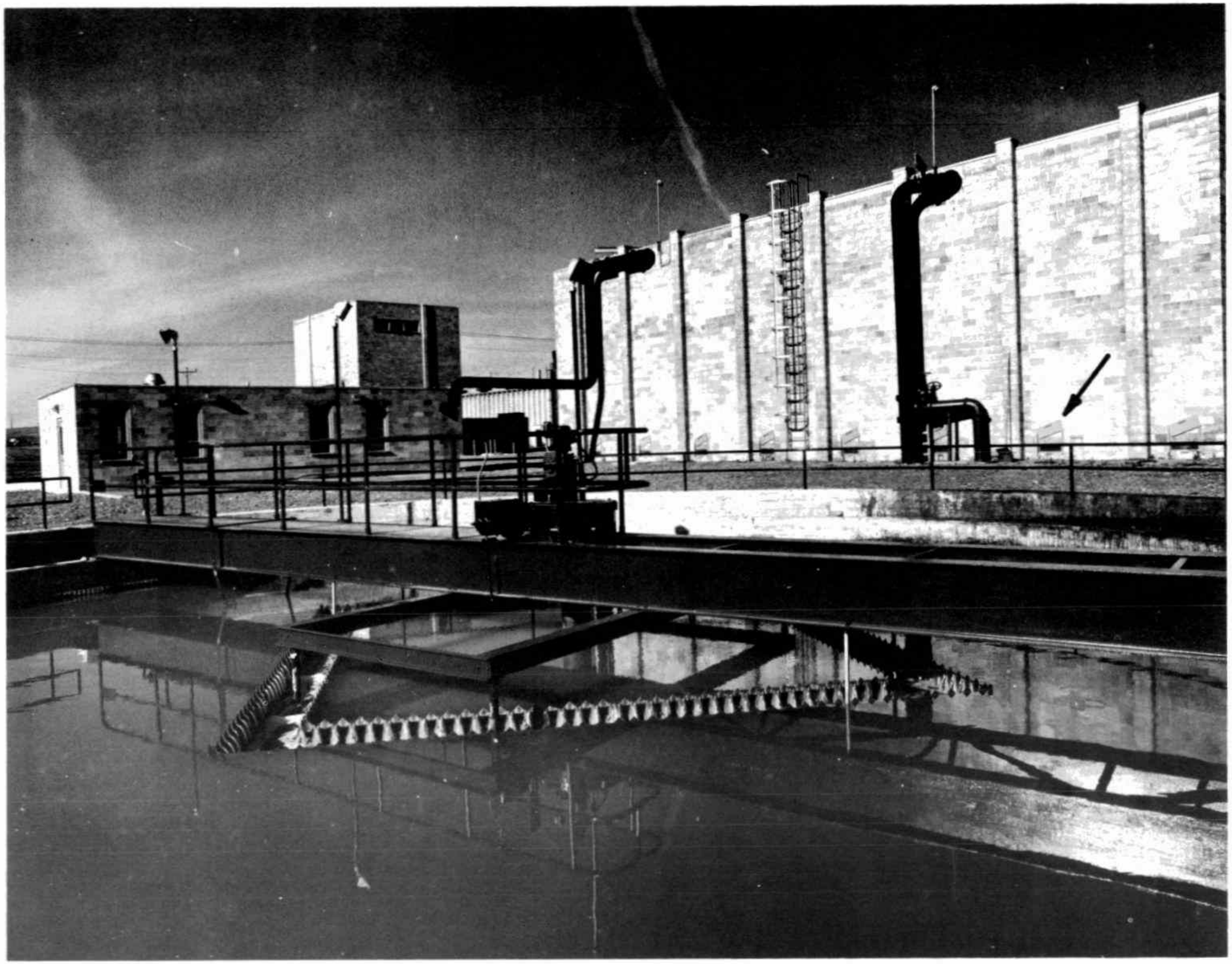

FIG. 10 BIOLOGICAL TREATMENT : LEFT TO RIGHT - CONTROL BUILDING, BIOFILTERS AND FINAL CLARIFIER (FOREGROUND)

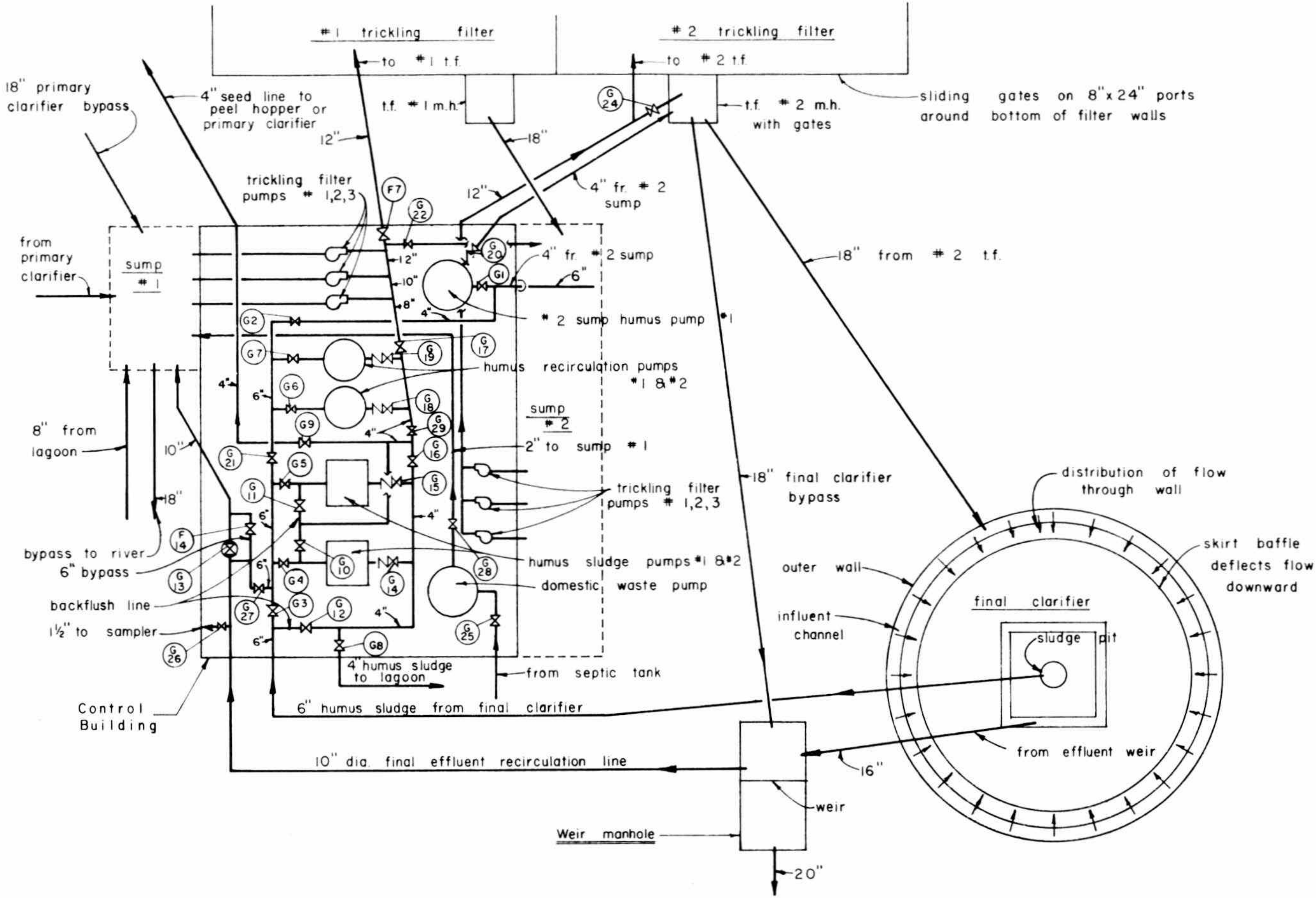

FIG. 11 TRICKLING FILTERS AND HUMUS SLUDGE HANDLING

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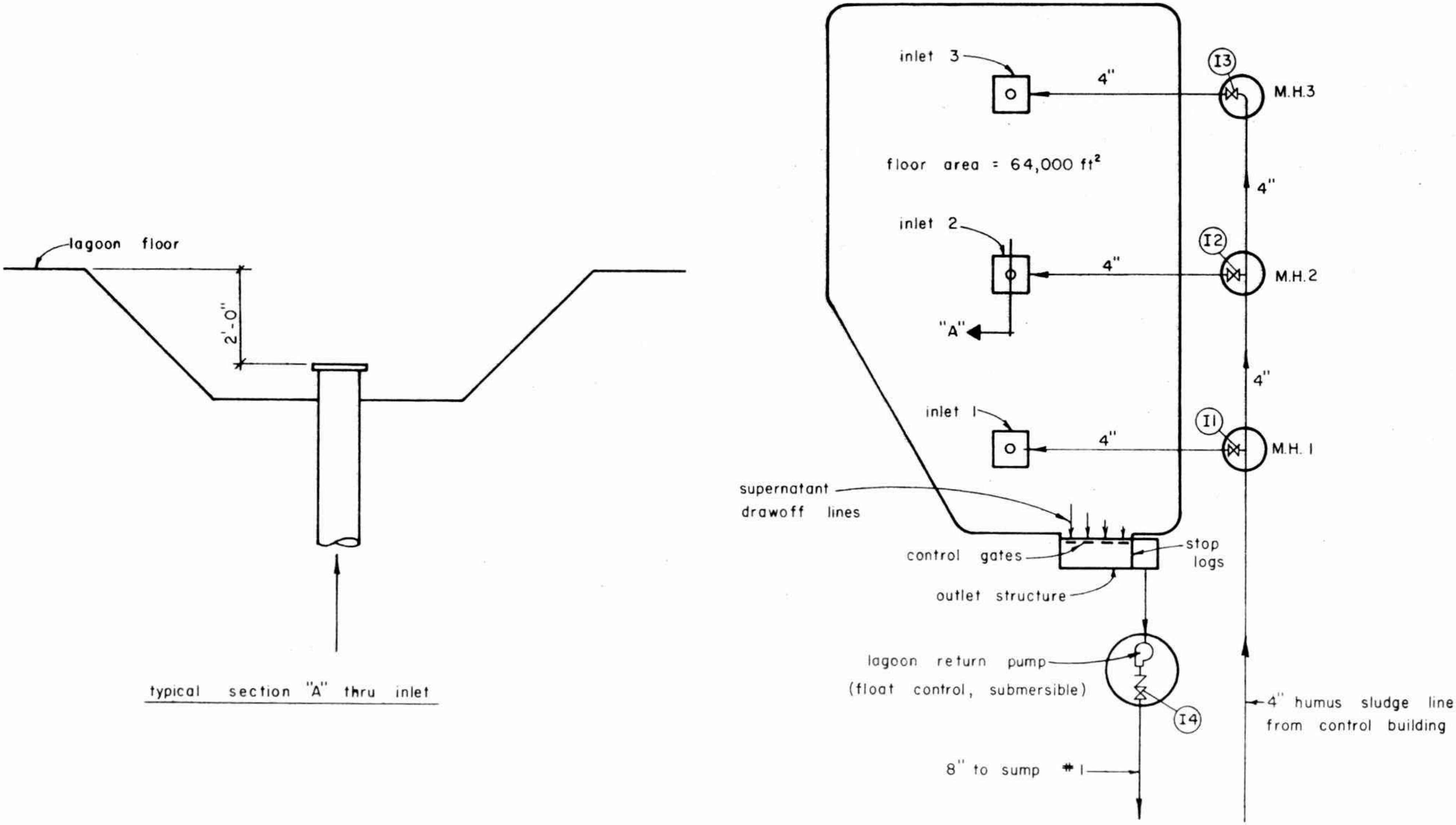

FIG. 12 SCHEMATIC OF SLUDGE LAGOON

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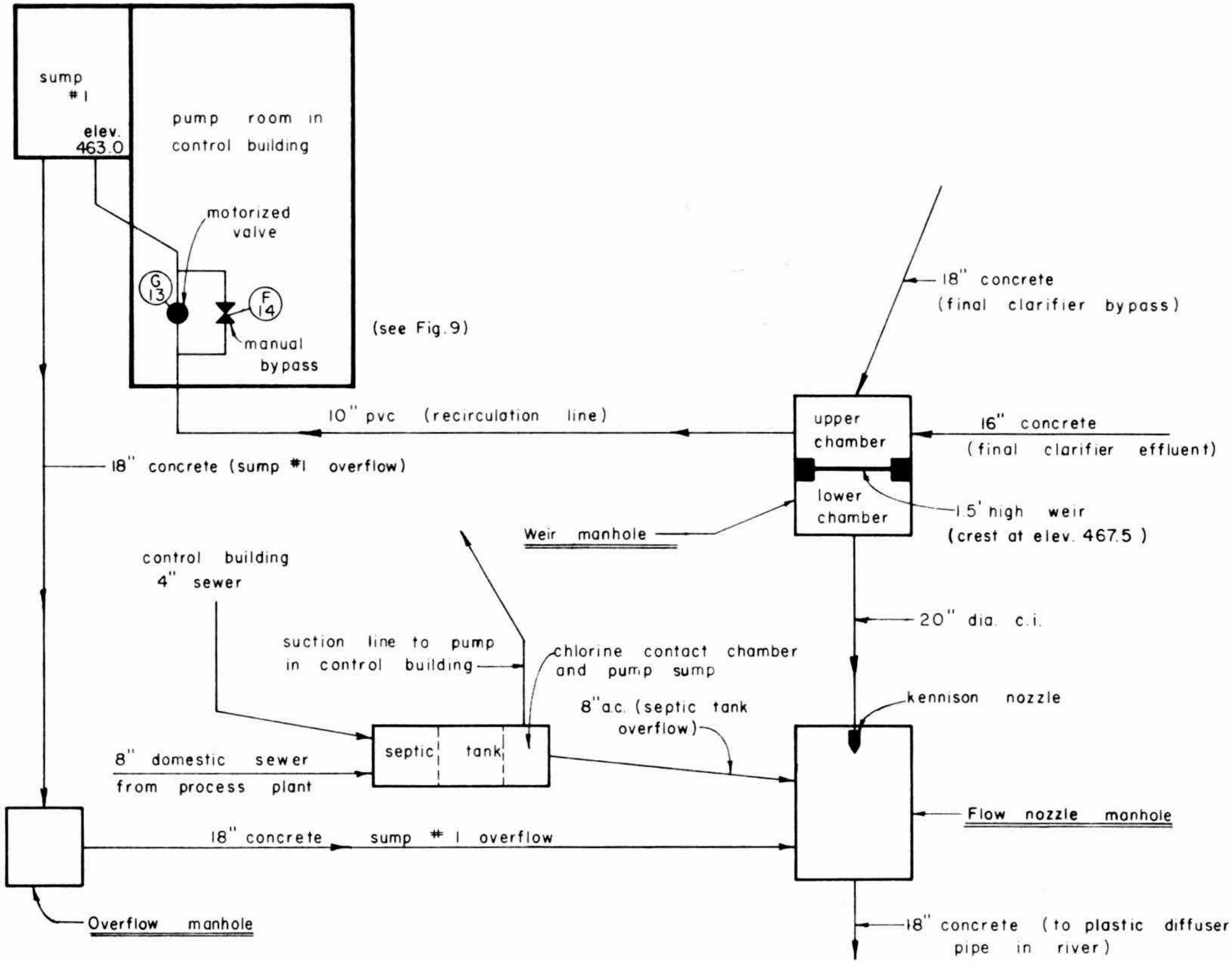

FIG. 13 SCHEMATIC OF CONTROL MANHOLES AND DOMESTIC WASTEWATER SYSTEM

A D I LIMITED

WASTE WATER EFFLUENT TREATMENT AT H. J. HEINZ PLANT IN LEAMINGTON

BY

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C. B. Coyle

The Heinz Plant at Leamington covers an area of some 30 acres and is located in the heart of the lush fruit and vegetable growing areas of Essex and Kent counties. Each year some 4,000,000 bushels of tomatoes are converted into a variety of sauces and canned foods. In addition, peaches, pears and apples, as well as a host of vegetables including cucumbers, peas, beans, squash and carrots, are processed through the production lines.

Typical products produced are baby foods, spaghetti, mustard, vinegar, sauces, soups and juices.

As early as 1949, Heinz installed a screening plant for more effective collection of tomato waste during the peak summer season and vegetable waste during the fall.

In 1964, Heinz entered into a joint venture with the municipality for a pollution control plant incorporating screening of all wastes on a year-around basis. The resulting effluent, although low in suspended solids and free of pathogenic organisms, still had a high B.O.D. on discharge through a long outfall into Lake Erie.

In 1969, Heinz engaged Chemetics Engineering Ltd., a Vancouver-based firm, to undertake an experimental study of the most efficient and economical means of eliminating the remaining organic pollutants from the waste water.

Three basic methods of waste treatment were considered, viz. (1) Spray irrigation, (2) Trickling filter, and (3) Activated sludge. Because of the high land values in the area and the volume of effluent to be treated, a spray irrigation system was not considered to be practical. The trickling filter process, although very effective, would not by itself provide the required level of B.O.D. reduction and would only be the first step of a complete pollution abatement program. This left the activated sludge process as the most appropriate method of providing for a complete treatment of the waste water. Complete treatment would require about 95% B.O.D. removal.

In order to establish the necessary design parameters, it was decided to install and operate a pilot plant so that the response of the waste could be determined experimentally.

The pilot plant consisted of three units:

(1) A trickling filter tower containing "Flocor", a plastic packing material.

(2) A nine-foot deep aeration basin through which air was bubbled.

(3) A clarifier to separate the sludge from the waste water.

A schematic drawing of the pilot plant is shown in Figure 1. Screened raw waste was pumped to the top of the "Flocor" trickling filter. The waste then trickled through the packing and was collected in a sump underneath the filter unit. From here it was pumped through a metering device to the aeration basin. From the aeration basin the waste was again pumped through a metering device either directly to the sewer or to a final clarifier.

The pilot plant also included provisions for automatic collection of 24-hour composite samples of waste at several points throughout the plant. Nutrients (nitrogen and phosphorous) were added by means of a metering pump and any required pH control was also achieved through this feeder.

The pilot plant was started up in September 1969. It was started by filling the aeration basin with settled domestic

sewage. The aerators were turned on and, after one week, the mixed liquor of the aeration basin along with raw waste was recycled through the "Flocor" filter. Within a few days a good biological growth had developed in the overall system. The pilot plant was seeded with domestic sewage to help ensure that the growth would be mainly bacteria as opposed to fungi. If a biological system is started with a carbohydrate-based waste such as that of a food industry, fungi often form and these are usually undesirable since they adversely affect the settling characteristics of the treated waste.

The pilot plant was operated at various organic and hydraulic loadings and critical data was collected and evaluated. It was found that under optimum operating conditions, the treated waste water had a total B.O.D. of less than 20 mg./l., was water white, and free from objectionable odours.

On the basis of the data resulting from the pilot plant study, the decision was confirmed to install an extended aeration system. The pilot plant study demonstrated that this method of biological treatment can oxidize essentially all of the compounds that contribute to the biochemical oxygen demand of the wastes and that the effluent can be guaranteed to have a total B.O.D. of 15 mg./l. or less.

The extended aeration system, like the aerated lagoon system, is a modification of the conventional activated sludge process. However, it differs from the aerated lagoon system in that the microbial solids are separated in a mechanical clarification system and recycled back to the aeration basin. A typical flowsheet is shown in Figure 2.

Screened waste flows by gravity to a collection sump where it is mixed with recycled microbial sludge from the mechanical clarifier. The combined raw waste and sludge mixture then flows by gravity to the aeration basin. The organic loading applied to the aeration basin is such that mixing and turbulence caused by the aeration equipment is sufficient to maintain the micro-organisms in suspension. The mixed liquor (treated wastes and suspended micro-organisms) flows from the aeration basin into the mechanical clarifier. In the clarification system, the microbial solids separate from the waste water and are recycled back to the aeration basin. The treated waste overflows to the receiving water.

Depending on the organic loading, the required quality of the wastes, and so on, a portion of the microbial solids that

are produced in the system, is wasted. The excess sludge can be trucked to a land disposal site as is, or through a mechanical dewatering system. The oxygen required to stabilize the waste is supplied by mechanical aerators. Nutrients are supplied as required for optimum biochemical activity.

Soil testing for the Heinz treatment plant showed the proposed site to have a heavy deposit of blue clay. This was an ideal material to line the aeration basin as it has excellent water-holding characteristics and will not slough off and contaminate the system.

The aeration basin is 234 feet square and has an operating depth of 13 feet. The banks are sloped at a 3:1 gradient and are protected at the water level by rip rap. Platforms for mechanical aerators are located in each quadrant of the lagoon and in the exact centre. A 150 H.P. aerator is currently being installed on the central platform. The outer four platforms are each equipped with a 75 H.P. aerator. The operating capacity of the lagoon is 4 million gallons. The lagoon is fed through a double-gated weir at the centre and the effluent flows through a second double-gated weir at the mid point of the east bank.

The clarifier has a diameter of 120 feet and a side wall depth of 14 feet. Its operating capacity is approximately 1,000,000 gallons. The settled microbial sludge is raked to the centre of the clarifier and either pumped back to the aeration basin or to the filter unit for dewatering and disposal. The clarified effluent overflows the clarifier to the outfall where it joins the effluent from the municipal treatment plant.

The plant underwent hydraulic testing in May of 1971. In mid June, the lagoon was seeded with municipal waste and actual treatment of Heinz waste began in July 1971, and since that date all Heinz waste has passed through the plant.

Both phosphate and nitrogen had to be added during season, the former at approximately 1 lb./100 lbs. B.O.D. and the latter at approximately 5 lbs./100 lbs. B.O.D.

The aqua ammonia was a 16-24% solution and the phosphate was added as Di-Ammonium phosphate solution. Further adjustments in nutrient addition had to be made in late fall as the tomato waste was replaced by apple and pear wastes with a resulting shift in pH to the more acid side.

The settling characteristics of the waste can be greatly affected by the mix of products being produced at the plant. For

example, a high carbohydrate waste as that resulting from bean and spaghetti blanching operations produces a floc with poor settling characteristics and generally requires an adjustment in the rate of sludge removal.

During December, the manufacturing operations at the plant were shut down for a holiday period from December 17 through January 4. Prior to this we began introducing municipal waste into the system so that adequate flow rates and good biochemical activity could be maintained. This also gave us an opportunity to check the compatibility of the municipal waste with the plant wastes.

During this period, it was no longer necessary to add nutrients as the town waste contained sufficient levels of both phosphorous and nitrogen.

The system continued to operate well with effluent B.O.D. averaging 15 ppm or less. These tests provided a good demonstration of the flexibility of this type of treatment system and its ability to adapt to a wide range of waste characteristics and still provide adequate reduction in B.O.D. loadings.

During the first two weeks in January, the rate of flow of municipal waste was gradually decreased until the system was once again on 100% plant waste.

Severe icing conditions were encountered during late January. This was especially evident on the aerator platforms and pads. During one especially cold weekend, the clarifier iced over and the rakes were immobilized. Warm water from the clean water outfall was pumped into the clarifier to melt the ice and no serious damage resulted. The efficiency of the system was not affected by the near-freezing temperatures.

In April of this year Heinz entered into an agreement with the municipality to treat the municipal waste through the extended aeration system. This joint treatment is limited to nine months of the year when excess capacity is available. No municipal waste can be treated during the summer processing season. The municipality is actively proceeding with plans to expand its own facilities to permit complete treatment of all municipal waste on a year-round basis.

The arrangement with the municipality is unique in that most industries have their wastes treated by the local municipality. In our case, the municipality is using the company facilities for secondary waste treatment.

This is an excellent example of the good relationship that has existed and continues to exist between the town and the company. A spirit of cooperation and goodwill has been established over many years, to the mutual benefit of both parties. The combined waste treatment program is but one more example of this "good neighbour" policy.

Efficient sampling devices are essential in controlling and monitoring a pollution control plant. We have had the best success with the dip type which operates by lowering a metal cylinder on a nylon cord into the water to be sampled. In severe cold conditions, the sampling frequency has to be increased in order to prevent the lines and the pulleys from being locked up by ice. In summer conditions, the sample storage must be refrigerated. We have found the samples based on interval timing to be the most reliable and the frequency of sampling can be increased to the point where a good representative sample is obtained.

The Heinz waste treatment plant has been in operation for only one year, but has proven its ability to meet its design load.

Current modifications involving improved in-plant waste collection, modified screening techniques and additional aeration capacity, will ensure that the plant can continue to cope with peak seasonal loads and projected plant growth while still meeting all current water quality standards.

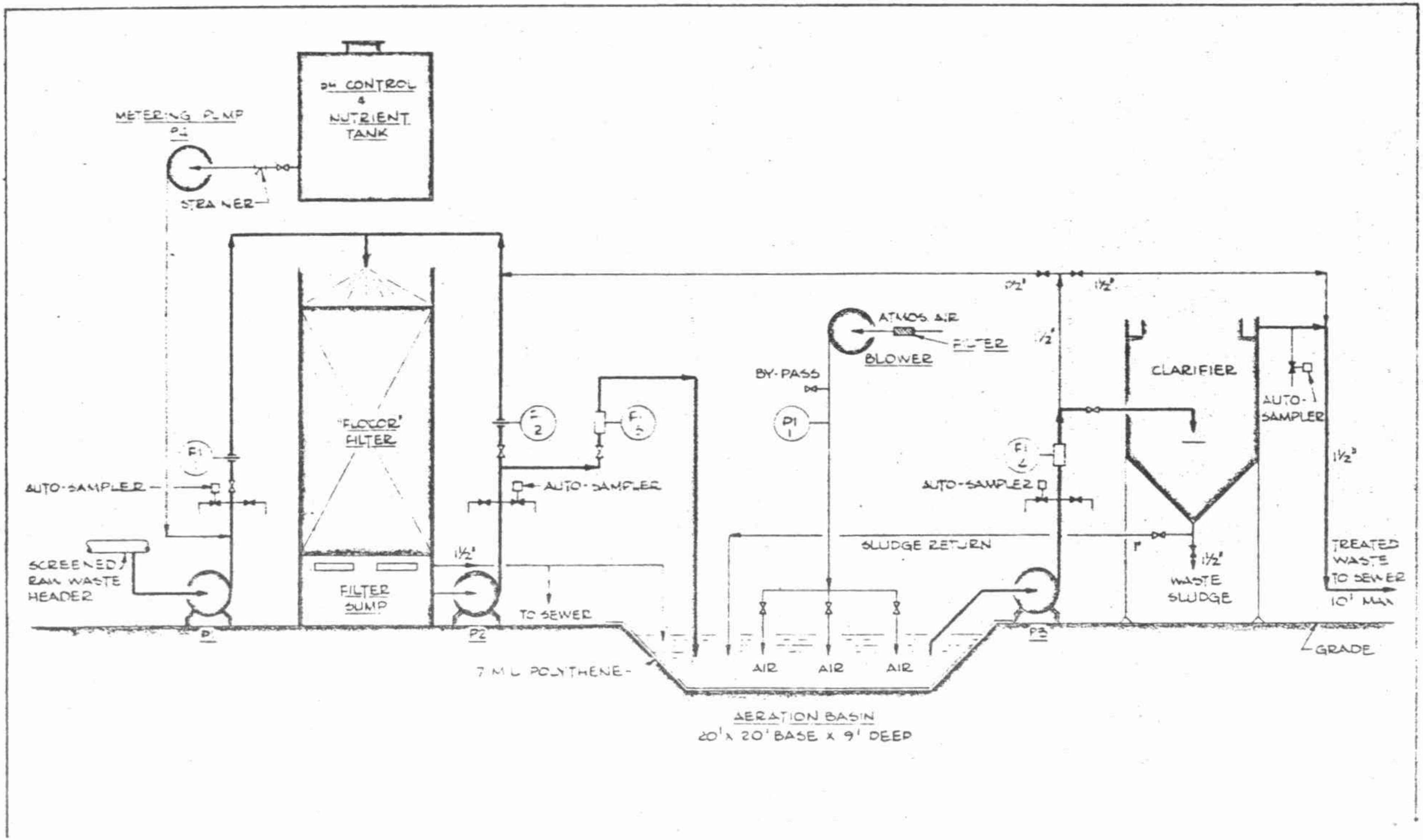

Figure 1. PILOT PLANT USED FOR BIOLOGICAL TREATABILITY STUDY

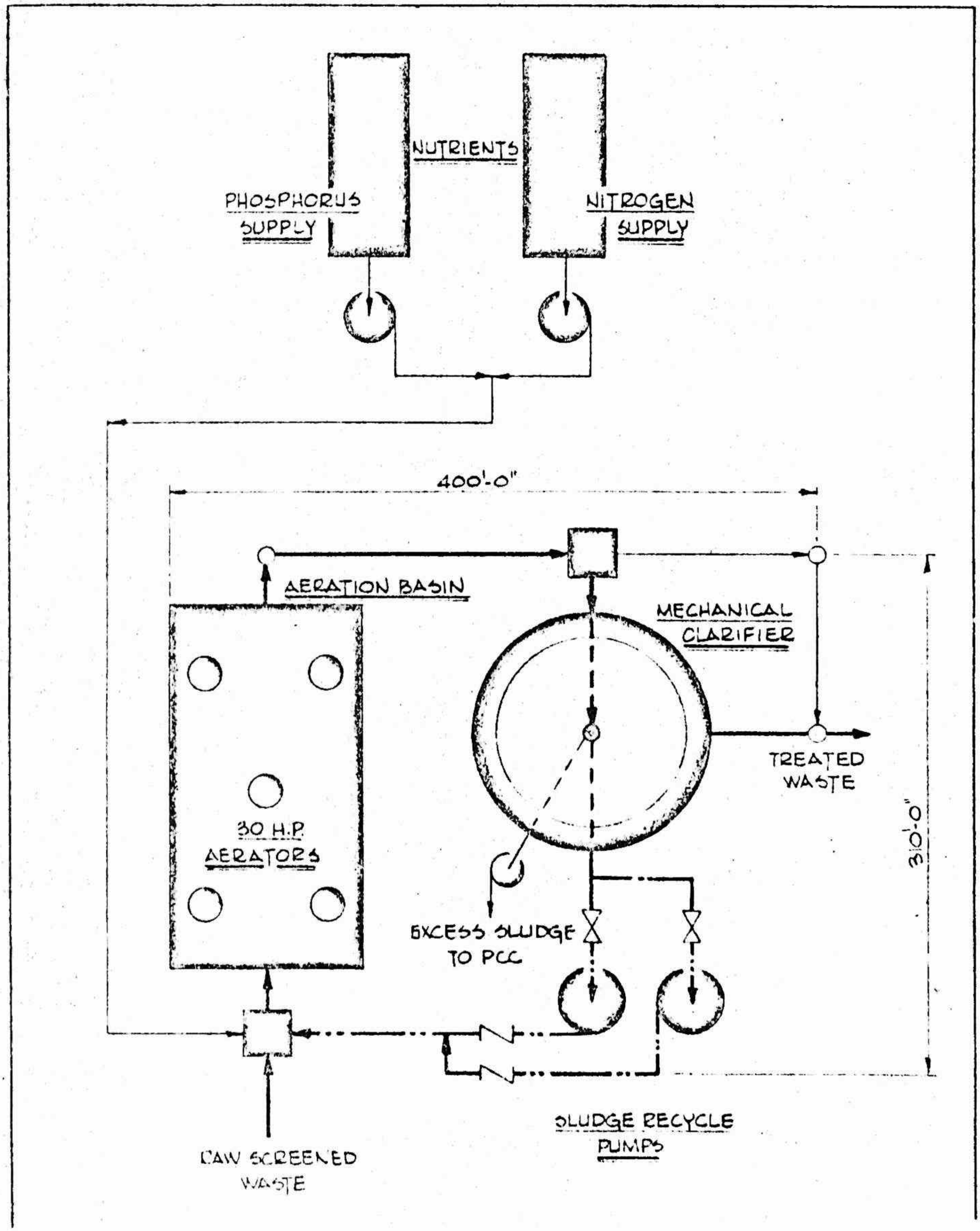

Figure 2. EXTENDED AERATION TREATMENT SYSTEM

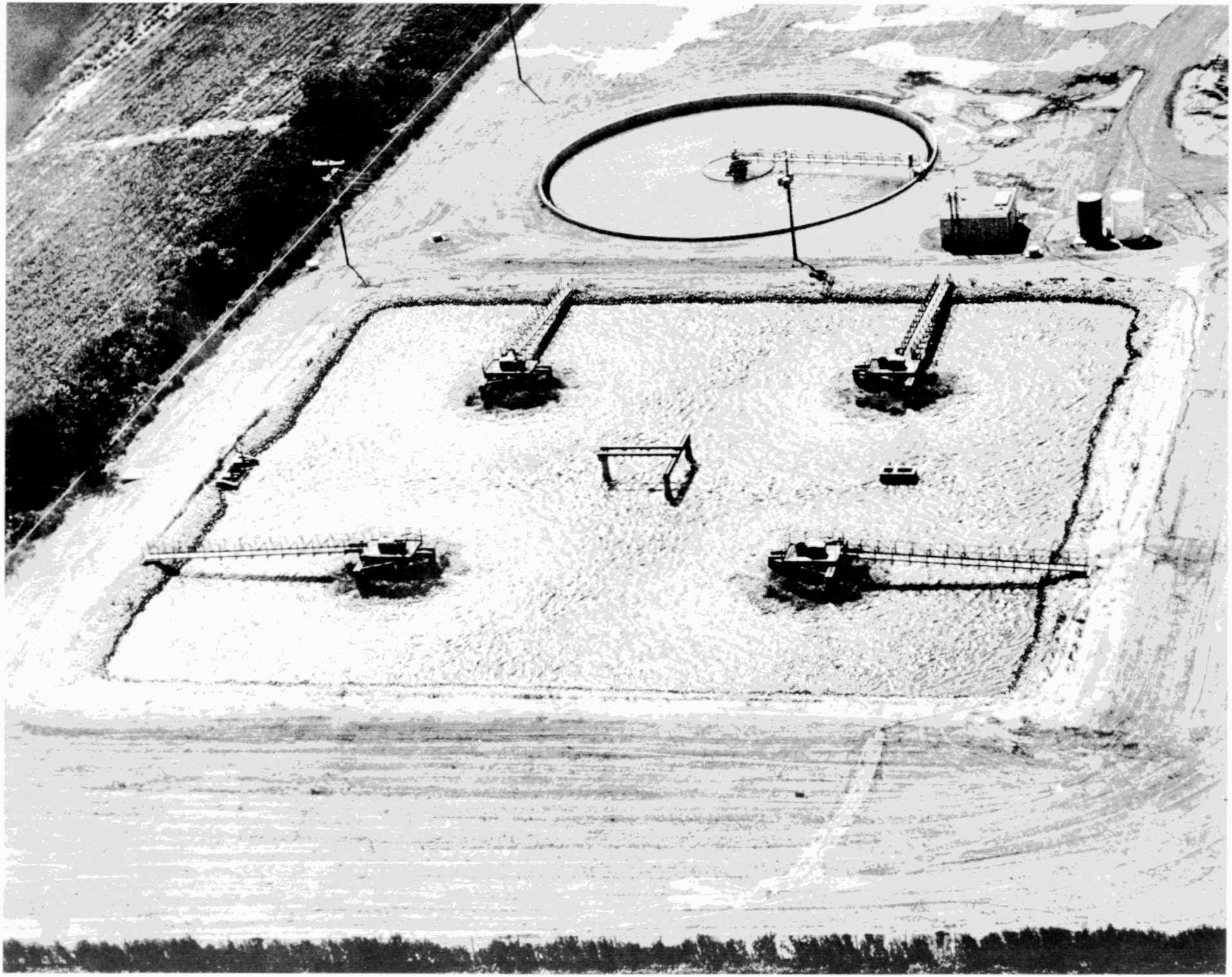

Fig. 3. Aerated Lagoon, clarifier, pump house and nutrient feed tanks for H. J. Heinz fruit & vegetable waste at Leamington.

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ATOMIC ENERGY OF CANADA LIMITED,
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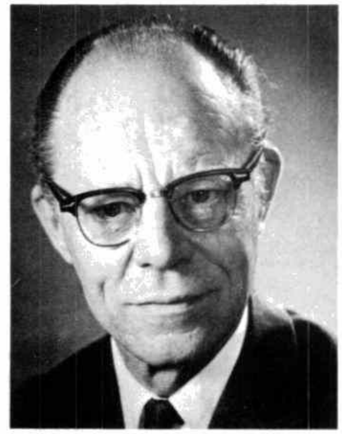

R. W. Dunn

THE POLLUTION CONTROL PROGRAM OF RIO ALGOM MINES LIMITED IN THE ELLIOT LAKE REGION

Part I Tailings Revegetation

BY

R. W. DUNN,
SENIOR RESEARCH ENGINEER

L. A. MELIS,
RESEARCH ENGINEER

L. A. Melis

A. J. Vivyurka

Part II Seepage Treatment and Control

BY

A. J. VIVYURKA,
RESEARCH ENGINEER

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ELLIOT LAKE, ONTARIO.

INTRODUCTION

BACKGROUND

The Elliot Lake uranium deposits are situated in Ontario in an area just north of Lake Huron. The development of the uranium deposits in this region dates back to the mid 50's when, having gained contracts to supply the uranium stock-piling program of the U.S. Atomic Energy Commission, many operators, both large and small, set up mining operations. In the early 60's, when the contract extension options were not taken out by the A.E.C., and, as world uranium demand had not grown as predicted, many mines closed or merged into larger operations. As a result there are only two operating companies in the Elliot Lake region, one of whom is Rio Algom Mines Limited.

In the ore, the uranium and other radioactive minerals are associated with iron pyrite. The uranium is only present in small quantities and a ton

of ore usually has to be mined to produce 2-3 lb. of the metal. A simplified flowsheet of the extraction process is shown in Figure 1. The uranium is extracted by crushing and grinding the ore to a fine sand followed by leaching with sulphuric acid. After neutralization of the excess acid, the solution is separated from the solid waste, the latter now being called tailings. The clarified solution is treated by ion exchange to remove the uranium which is then further processed to produce the final uranium concentrate. Meanwhile, the barren solution which has been stripped of uranium is mixed with the solid tailings waste to produce a slurry. This slurry is neutralized with lime to a pH of order 10 before being discharged to the tailings dam disposal area.

At the time of development, all mining operations complied with the then existing regulations regarding the disposal of tailings and mill effluents. However, the shut-down mines that have resulted from this earlier development have now left the Company with a legacy of inactive tailings dams that are causing pollution problems in the context of recent legislation. This paper deals with the research presently in progress and the implemented and proposed abatement programs directed towards the control of these pollution problems.

THE NATURE AND SOURCE OF POLLUTION FROM INACTIVE TAILINGS

There are two types of pollution associated with our inactive tailings. Firstly, there is dust blown from the surface of the tailings, and secondly, seepage from the base of these inactive tailings dams. This seepage is of low pH and contains dissolved calcium sulphate, heavy metals and trace amounts of solubilized radioactive elements. The origin of the dust is obvious, however, the origin of the acidic seepage is less clear. As mentioned earlier, the tailings produced in the extraction process are limed and discharged at a high pH, of order 10. On becoming inactive, the pyrite in the surface of the tailings chemically oxidizes forming sulphuric acid. This slow process eventually lowers the surface pH to around 4. At this pH a strain of bacteria, Thiobacillus Ferrooxidans, starts to attack the pyrite and oxidation, and the consequent production of sulphuric acid, occurs at a much faster rate. This causes the pH in the surface of the tailings to rapidly drop to the region of 2.

The net movement of water in the tailings is downward, consequently, the acid produced in the surface seeps through the underlying tailings, leaching acid

soluble salts and radioactive elements as it goes. After several years, this seepage reports to the base of the dam and hence to the watershed system.

PART I: TAILINGS REVEGETATION

The objective of stabilizing the surface of tailings is to primarily eliminate the dust problem. When considering methods of stabilization, three potentially economic possibilities exist:

1) physical, by covering the surface with crushed rock, slag, etc.,

2) chemical, by the application of materials that will bind the surface together, and

3) vegetative, whereby the surface is bound by the root structure of the vegetation.

Aesthetically and economically, vegetative stabilization is by far the most attractive, and offers additionally the possible benefit of reducing both the volume and acidity of seepage. Chemical stabilization is initially less expensive than vegetation, but requires a much higher maintenance cost due to the breaking up of the surface by extremes of precipitation and temperature. The cost of physical stabilization is prohibitive if a supply of inexpensive sealing material is not readily available.

The research effort of Rio Algom has been orientated to the development of a technique for vegetative stabilization of acidic tailings. In order to do this, the problems that needed to be overcome were associated with the differences between tailings in the Elliot Lake region and in normal soil. These differences are:

1) Lack of nutrients.

2) Unconsolidation of the surface. This gives rise to water erosion, particularly on slopes, and wind erosion, causing "sand-blasting" of young plants. Unconsolidated fines have poor load bearing properties when wet and do not allow good root aeration.

3) Low cationic exchange capacity (CEC). It is the CEC of the soil that allows it to store nutrients for the plant. When the CEC is low, nutrients leach out rapidly.

4) High reflectivity. This can lead to the burning of young plants in summer.

5) Low pH, of order 2 to 3. This results from the bacterially assisted oxidation of iron pyrite in the tailings. At this pH any applied nutrient is unavailable to the plant and heavy metals are released in toxic quantities.

Solutions to the first four problems exist and have been applied elsewhere. Lack of nutrients can be amended with fertilizer applications. Unconsolidated tailings can be temporarily bound by chemical stabilizers that do not affect vegetation, and load bearing can be increased by drainage. The CEC can be improved by the addition of organic mulches such as bark, straw, garbage, etc., or the nutrients can be added more often. Mulches can reduce reflectivity as does a fast-growing companion crop.

Tailings having all the adverse properties of those in the Elliot Lake region, except low pH, have been successfully stabilized with vegetation in Timmins and Gaspé areas and other instances of success are known. Therefore, it may be concluded that neutral tailings can be vegetated with minimum difficulty.

Acidic tailings have less instances of success. Slightly acidic tailings, those of the International Nickel Company (Inco) at Copper Cliff and the Pennsylvanian coal strip mines, have been corrected with applications of crushed limestone; at Inco 5T/acre have been found to be sufficient initially, with periodic top dressing to correct recurring acidity. In South Africa, limestone applications were unsuccessful on the very acidic tailings of Witwatersrand. Here a leaching technique was developed where water misting sprays produced just sufficient water to match the tailings permeability and this moved the acid down from the surface. This technique was only successful on aged tailings. Limestone applications of up to 10T/acre have proved insufficient in work so far done in the Elliot Lake region and at Falconbridge, Ontario.

With regard to the vegetation, the varieties usually sown in tailings are of the "poor pasture" type; those with a high tolerance of acid soils, wet and dry conditions and low fertility soils. These have been preferred to native varieties because of the availability of seed. The root structure of grasses and legumes binds the tailings together (sod-forming) and start the natural process whereby the tailings will become a soil. Once the tailings are more consoli-

dated, consideration can be given to the growing of trees. These may volunteer naturally as has occurred at Timmins and Inco at Copper Cliff.

RESEARCH PROGRAM

It was realized that the problems associated with the vegetation of our acidic tailings interacted to produce an unusually hostile environment when a vegetation stabilization contractor, with a record of success elsewhere, had been unsuccessful after two growing seasons to vegetate our tailings. After the first failure, a research program was instigated in late 1970 aimed at developing methods of converting the hostile surface environment to one conducive to the establishment of vegetation. Here follows a review of research completed and in progress and the limited conclusions that have so far been reached.

Winter, 1970-71

Initial research was orientated towards techniques to neutralize the surface acidity. Three techniques were tried in the laboratory; these were

1) application of lime and crushed limestone,

2) water spray leaching, and

3) combinations of these methods.

From these tests, it was concluded that an application of 10T/acre of crushed limestone would be sufficient to neutralize the tailings in one month. Ancillary growing tests to determine the suitability of selected varieties of vegetation were carried out by planting the seeds in neutralized tailings.

Summer, 1971

Nordic Area Survey

It was planned to carry out statistically designed summer field tests on the 170 acre tailings area of the inactive Nordic mine; the acreage to be used for these tests being 32 acres. In order to gain an idea of what we were dealing with, and to correctly position the field tests, the entire area was sampled on a 100 yard grid pattern for particle size, pH and acidity, each sample being a composite of the top 6 inches. The particle size distribution (Figure 2) was found to be quite broad. This reflects the natural segregation of the tailings as the more coarse particles

settle out near the spigot, whilst the slimes are carried closer to the decant area. The pH of the tailings (Figure 3) was predominantly acid, being in the range 2.5 to 3. The average total acidity required less than 1T/acre of limestone in the top 6 inches to complete neutralization whilst the maximum for any sample was 4.6T/acre.

Field Experimental Plan

At this stage we had three guides as to the correct limestone application for neutralization of the top 6 inches of the tailings.

1) 5T/acre would cover the maximum theoretical requirement.

2) 10T/acre had been sufficient in the laboratory but insufficient in previous field work.

3) The Ontario Agricultural College (O.A.C.) had recommended 15T/acre.

It was decided to apply 20T/acre of a coarse grade of limestone (50% passing 10 mesh and 15% passing 100 mesh) so as to provide sufficient fines for immediate neutralization and coarse material for a long-term effect.

The grade of fertilizer used was 5-20-20 (5% nitrogen as N, 20% phosphorous as P_2O_5, 20% potassium as K_2O), this being the grade found most suitable for tailings revegetation by Inco. The fertilizer was to be applied along with the limestone in early June. This was to allow six weeks to neutralize the tailings and to build up soil fertility before seeding in late July.

The basic agricultural aspects of the experiment had been largely based on the successful procedure developed by Inco. To this were added agricultural variables that were thought to offer potentially economic improvement of vegetative cover. A range of agricultural variables were statistically designed into the experiment. These were:

1) Type of seed blend. Whether the blends should consist of grasses and legumes or grasses alone.

2) Mulch in order to enhance the CEC and moisture retention. In this case a locally available barkfines material, produced in the de-barking operation of a local wood chip mill.

3) Chemical binder to hold down the wind-blown tailings and prevent "sand-blasting" of the young seedlings.

4) Depth of working of the limestone to prevent upward movement of acidic seepage in dry weather.

5) Irrigation.

6) Fast growing companion crops to shelter the slow growing seedlings from wind and sun.

In addition, the Company had allowed the dumping of sewage sludge from the Elliot Lake Sewage Treatment Plant on one section of the Nordic tailings. In order to assess the usefulness of the sludge as a fertilizer, it was proposed to seed this area after it had been treated only with limestone.

The work planned called for the application of limestone and the bulk of the fertilizer by middle June and the seeding, additional fertilizer, mulch and chemical binder application by the end of July. The work was to be done by the vegetative stabilization contractor who would dovetail work on the research plots with the re-doing of his own area.

Execution of the Field Experiment

Various difficulties caused the first part of the program to be delayed until early July. In order to speed neutralization, 5T/acre of the 20T/acre of limestone was replaced with an equivalent amount of lime. This still did not give adequate time for neutralization to take place by the planned time of seeding. However, to have excessively delayed seeding would have left the young plants insufficiently strong enough to survive the winter, consequently, in the hope that neutralization would have taken place by the time the young plants were ready to absorb nutrients, seeding was carried out in early August. Further difficulties prevented the spreading of barkfines and chemical binder.

Meanwhile, the nearby area worked by the vegetation contractor had been limed with 20T/acre of limestone, fertilized and seeded by the end of July.

Preliminary Assessment

Germination in both the research and contractor's areas was good, except for the legumes. In a survey carried out in early September, growth was judged to be retarded because of the acidity of the tailings,

being still generally in the pH range 2 to 3. Growth in the contractor's area was better for the two weeks longer growing period. However, it was anticipated that the plantings in both areas would not be strong enough to survive the winter. On the other hand, the sewage sludge plot was doing exceedingly well and, if anything, troubled by excessive growth and smothering.

In early October, a pH survey of the research areas was carried out to determine the response of pH to the limestone treatment. These results are shown in Figure 4. It can be seen that the response was very sporadic and that, in the areas that had not responded to the treatment, the pH had dropped by about half a pH unit from May to October. The vegetation, on the other hand, had responded to rainfall and an unusually mild Fall period. It was now judged to be strong enough to withstand the Winter. The mild Fall had also increased the nutrient requirements of the plants and nutrient deficiency symptoms were noted. To amend this, and to provide nitrogen for the plants in the Spring, additional fertilizer and coated urea were applied.

Fall, 1971

The most significant result of the Summer field work had been the demonstration of poor correlation between laboratory tailings neutralization results and those in the field. In the laboratory, 10T/acre of limestone had been sufficient to give neutralization in three weeks whilst the use of lime gave immediate results. In the field 15T/acre of limestone and an equivalent of 5T/acre of limestone as lime was insufficient. This conflict of results was attributed to the difference in mixing capability of agricultural equipment compared with laboratory mixers, the former leaving discreet pockets of tailings in the cross-section still acid. The low solubility of lime and limestone did not allow normal precipitation to complete the neutralization process.

Two methods of overcoming this problem were conceived. The first method involved using more soluble neutralizing agents such as sodium carbonate (soda ash) and ammonium bicarbonate. It was envisaged that just sufficient of the more expensive soluble agent would be used to neutralize existing acidity, of order 2T/acre, and that the limestone could then maintain the neutrality. A small field test, using up to 4T/acre of sodium carbonate and up to 3T/acre of ammonium bicarbonate in conjunction with 20T/acre of limestone, gave most encouraging results. Further work was there-

fore planned on this method for the Winter laboratory research program.

The second method consisted of using limestone but applying it the season before planting in order to allow time, and the slower rate of acid production in the colder temperatures, to assist the neutralization process. Limestone at a rate of 20T/acre was applied to 4 acres of tailings in the Fall. Ideally it would be desirous to seed this in the following Spring, however, at this time of year, the wet tailings will not support equipment. Therefore, it was decided to use a seeding technique known as dormant seeding. This involves seeding in the Fall so that the seeds do not germinate until the next Spring. The 4 limed acres were therefore seeded in the late Fall, the seeds being broadcast with the fertilizer.

Winter, 1971-72

The main work here was the laboratory evaluation of the soluble carbonate salts as neutralizing agents. Both sodium carbonate and ammonium bicarbonate were considered, as both had been as effective in neutralizing the tailings in small scale tests. Sodium carbonate was preferred on a cost basis but there was concern that the introduction of a large amount of sodium ion to the soil would displace other exchanged nutrients producing a salinity problem. However, assurances were given by the O.A.C. personnel that this would not occur for the treatments we were contemplating, as normal precipitation should wash the sodium ions from the surface. Sodium carbonate was therefore used in the laboratory experiments.

The variables used in the laboratory research program were

1) limestone,

2) sodium carbonate, and

3) level of mixing.

Three levels of mixing were used; bad, where the neutralizing agents were just placed on the surface of the tailings, poor, where the neutralizing agents were just loosely mixed with the surface, and good, where the neutralizing agents were intimately mixed with the tailings. The stable pH's after 10 weeks of solutions draining from the test vessels, each of which received the daily normal precipitation, are shown in Table 1.

TABLE 1

NEUTRALIZATION EXPERIMENT RESULTS

NEUTRALIZING AGENT		MIXING		
Soda Ash	Limestone	Bad	Poor	Good
T/acre		pH		
0	0	2.75	2.64	2.70
0	20	3.00	6.34	8.00
1	0	3.46	3.12	2.75
1	20	4.08	6.24	7.70
2	0	6.55	4.14	2.60
2	20	6.48	6.08	7.65

With only limestone, the effect of less than good mixing is highly significant in limiting the ability of limestone to neutralize the tailings. With soda ash alone the reverse effect is obtained in that bad mixing, that is just applying the material to the surface, is most effective. In this case, the sodium carbonate is washed through all the tailings whereas with good mixing the sodium carbonate under the tailings cannot neutralize the tailings above it. Using limestone and sodium carbonate together an adequately neutral condition was produced in the tailings using 2T/acre of sodium carbonate over the entire range of mixing levels. This result was obtained using tailings that had an acidity equivalent to 7-1/2 T/acre of sodium carbonate 6 inches deep. This is more acidic than any of the tailings samples taken from the Nordic area.

VEGETATIVE BUILD-UP OF RADIOACTIVE COMPONENTS

During the course of this research program, consideration was given to the possible accumulation of radioactive elements in plants grown on uranium tailings.

Two varieties of vegetation, Climax Timothy and Bulrushes, were sampled from the tailings, from beside highways in the mining area and from Southern Ontario well away from the mining area. The specimens were completely washed, in some cases dissected, and ashed. Analyses of the ash residues based on the original dried material are given in Table 2.

TABLE 2

ANALYSIS OF VEGETATION SAMPLES

SPECIES AND SOURCE	ELEMENT CONCENTRATION ON DRY MATERIAL BASIS		
	Ra pC/gm	U_3O_8 ppm	Th ppm
Climax Timothy			
- tailings	11.6	4.2	4.8
- Hwy. 17	0.057	2.6	1.7
- Guelph	0.135	1.4	0.4
Bulrushes			
tailings - whole plant	2.89	6.9	5.3
Hwy. 639 - whole plant	0.288	2.6	2.2
tailings - root section	3.94	19.7	17.9
Hwy.639 - root section	0.221	2.4	3.3
tailings - stock section	1.95	1.8	1.4
Hwy.639 - stock section	0.114	2.4	1.7
Guelph - stock section	0.040	3.9	2.7
tailings - seed section	1.36	2.4	1.6
Hwy.639 - seed section	0.115	3.0	2.0
Guelph - seed section	0.002	5.0	3.7

Compared to the control samples, the build-up of radium was orders of magnitude greater than the build-up of uranium and thorium. Similar results were found by other researchers. The dissected bulrushes showed varying concentration ratios of radium; from 12-1 to 18-1 compared to local reference samples.

At present it is not possible to be conclusive about the ecological significance of these results on wild life as all relevant government and research organizations that we have contacted have no effect results on which to base opinions. However, assuming radium will follow calcium and strontium in the body, radium will accumulate in the teeth, bones and milk of the grazing animal. Eating of the meat of the animal will therefore not pass on the radium and, as it is not contemplated to graze herds on stabilized tailings, no radium would get into milk for human consumption.

FUTURE RESEARCH

At the time of preparation of this paper, it was not possible to evaluate the Winter survival or Spring germination of the field test plots. Assuming satisfactory survival, it should be possible to statistically assess the effects of the agricultural variables in the experiment this season. This will be included in a program of continued maintenance of these areas with fertilizer and limestone.

The laboratory success of the soda ash/limestone method of neutralization of the tailings has prompted a more extensive field test of this method. This experiment is to be carried out with earlier neutralization and seeding than last year, both being brought forward about six weeks.

The research described in this paper has concentrated on the development of methods of neutralization of the tailings in order to raise the pH of the surface of the tailings to a region more suitable to the establishment of vegetation. Work on the physical agricultural problems has received a lesser priority because of the relative importance of these problems. It is, however, becoming increasingly obvious that the physical factors interact with the chemical/neutralization factors and consequently research into amending the physical factors impeding vegetation will be increased. In this regard we are receiving assistance from outside sources. At the start of the year 1971, interest in the problem of vegetation of mine tailings at the academic and governmental level was only beginning to develop. Since then, the Mines Branch of the Department of Energy, Mines and Resources has appointed a full-time agronomist to study the problem and he has established his field base at the Mines Research Centre in Elliot Lake. In addition, staff from the Ontario Agricultural College are now taking a research interest in the problem and are also taking, as an initial point of reference, the problem as it exists in the Elliot Lake region. Rio Algom Mines Limited is working in close co-operation with both these groups with whom joint field research programs will be carried out this summer.

PART II: SEEPAGE TREATMENT AND CONTROL

In the history of the Elliot Lake-Blind River mining district, from 1955 to the present date, Rio Algom Mines Limited has developed and acquired ownership of eleven mines (Figure 5). These mines are Quirke #1, New Quirke, Panel, Spanish American, Stanleigh, Milliken, Lacnor, Nordic, Buckles, Pronto and Pater. All of these

mines were operated at one time, for various periods, but are now idle except New Quirke. Uranium was produced at all of these properties except the Pater mine, which produced copper from 1960-1969. Processing of the ore from this group of mines was accomplished in 8 mills, with the resulting tailings being disposed of in 7 areas.

The original high demand for uranium led to accelerated programs to commence production as soon as possible. This condition, along with a variety of mining companies and operators utilizing various production and operating policies, and the lack of full knowledge by government and industry of the impact of mine-mill wastes on the environment, has left us with various situations developed in the 1950's and early 1960's which we are rectifying and clarifying today.

One of the situations that has been inherited is the handling and disposal of seepage and runoff from the inactive tailings areas. Conversely, treatment and control of effluents from the present operating sites were designed into the disposal system in consultation with government departments and based on the best current knowledge and techniques.

The level and form of dissolved constituents in runoff and seepages from tailings areas in the Elliot Lake-Blind River district will vary with each individual situation. Even within one tailings area the solution contents will vary considerably. This composition is affected by the amounts of fresh water runoff diverted into the area, the type of dam, permeability of the tailings to air and water, age of the tailings and the drainage characteristics (water table) caused by the topography. The effluent solutions developed at an operating property differ from those at idle tailings sites (Table 3). Active tailings basin discharge solutions are high in pH (6.5-9.0) because the effluent tailings from the mill are neutralized to pH 9-10 before discharge and heavy metal content is negligible. However, tailings in idle areas are more acidic (pH 2-6.5) with this condition arising by natural processes. This is one condition which became apparent after mining was conducted for some period in Elliot Lake and was not anticipated originally. Indications that acid formation would take place from tailings occurred in the underground workings when the mine water, used for drilling and washing, slowly started to drop in pH. Originally, mine water pumps were not acid resistant, however, caustic neutralization and/or stainless steel pumps soon had to be installed.

The ore, and subsequently the ground tailings, which is being mined contains 5-10% pyrite. Chemical and biologically assisted oxidation of this iron sulphide

material in the presence of water and oxygen results in the formation of sulphuric acid and iron sulphates, Equations 1-5[1].

$$2FeS_2 + 2H_2O + 7O_2 \rightarrow 2FeSO_4 + 2H_2SO_4 \quad (1)$$

$$FeSO_4 + 2H_2SO_4 + O_2 \rightarrow 2Fe_2(SO_4)_3 + H_2O \quad (2)$$

$$Fe_2(SO_4)_3 + 6H_2O \rightarrow 2Fe(OH)_3\downarrow + 3H_2SO_4 \quad (3)$$

$$Fe_2(SO_4)_3 + FeS_2 + H_2O \rightarrow 3FeSO_4 + S^0 \quad (4)$$

$$S^0 + 3O + H_2O \rightarrow H_2SO_4 \quad (5)$$

TABLE 3

SOLUTION ASSAYS

	ACTIVE TAILINGS AREAS DECANT AND SEEPAGE	IDLE TAILINGS AREAS	
		SEEPAGE	RUNOFF
*pH	6.5-9.0	2.0-6.5	3.0-4.5
TDS	1000-2500	1000-6000	300-1500
SO_4^-	600-1500	600-3200	200-1000
NO_3^-	100-200	5-10	5-10
NH_3	5-15	< 0.05-3	< 0.05-3
Ca	250-450	250-600	50-350
Fe^{+2}	< 0.1	10-400	5-20
Fe^{+3}	< 0.1	10-500	5-20
Pb	< 0.05	< 1.0	< 0.5
Zn	< 0.1	< 1.0	< 0.5
Cu	< 0.1	< 1.0	< 0.5
Mn	0.01-1.0	1-3.5	0.5-1.5
Ni	< 0.1	< 1.0	< 0.5
$Radium_{226}$ (pC/l)	10-100	10-300	< 1-100
U_3O_8	< 1.0	< 1.0	< 1.0

* All analysis in ppm except pH and $Radium_{226}$

From these equations it is evident that an effluent can have a range of iron content from the ferrous form of iron to the ferric. This is apparent in the solutions developed in the Idle Tailings areas (Table 3). In one tailings area, a seepage solution of pH 6.0 contains 150 ppm ferrous iron and 200 yards away another seepage has a pH of 2.8 with both ferrous and ferric iron present to the 400 ppm range.

The environment developed by the chemical oxidation products is one which accommodates a particular microbiological form of life. This microbiological group, Thiobacillus-Ferrooxidans, requires an environmental pH of 1.5-3.5 for optimum growth and life. This bacterial action enhances the oxidation of the iron from the ferrous to ferric state and the sulphur to +6 valence state, through various sulphur-oxygen radicals, to the sulphate form. This also, consequently, helps to oxidize the pyrite at a higher rate. Oxidation of the pyrite is a main source of contamination and without it our problems would be limited. From these acid forming reactions occurring in the tailings, other trace elements occur in solution due to the coincidental dissolution with the pyrite and to reactions of the acidic solutions with the other tailings constituents.

The balance of the other constituents which are in solution occur from the explosives in the mining operation and the milling process. These are essentially calcium sulphate from the lime neutralization of the acid used in leaching, ammonium and nitrate ions from the uranium ion exchange recovery operation and explosives, and radioactive constituents ($Radium_{226}$, thorium, rare earths). Trace amounts of other metals are dissolved in the acid leaching process; however, these, along with thorium, uranium and rare earths, are precipitated in the final tailings neutralization. Redissolution of these occur to a very limited extent in the tailings deposits.

The areas of solution treatment which we are presently engaged in are:

1. Neutralization of acidic effluents with lime, Equation 6.

$$H_2SO_4 + Ca(OH)_2 \longrightarrow 2H_2O + CaSO_4 \qquad (6)$$

2. Removal of metal cations by hydrolysis (hydroxides and hydrous oxide), Equations 7-8.

$$M^{+n} + n\ OH^- \rightleftharpoons M\ (OH)_n\downarrow \qquad (7)$$

$$yM^{+n} + 2n\ OH^- + (x-n)\ H_2O \rightleftharpoons MyO_n \cdot xH_2O\downarrow \qquad (8)$$

3. Removal of $Radium_{226}$ with barium chloride, Equation 9.

$$BaCl_2 + Ra^{+2} + 2SO_4^= \longrightarrow BaSO_4 \cdot RaSO_4\downarrow + 2Cl^- \qquad (9)$$

In Equation 6, neutralization with lime, calcium sulphate is produced and this constituent is the main source of total dissolved solids in our effluents. The solubility product allows a solution capacity of approximately 2 grams per litre of calcium sulphate ($K_{sp} = 1.95 \times 10^{-4}$ @ 10°C)[3]. Thus in the neutralization process in the mill and also in the field, calcium sulphate is easily leached from precipitate or tailings if the solution content drops below saturation equilibrium levels. Because of this we endeavour to keep fresh water runoff stream diverted away from tailings fields and allow mixing only after treatment takes place.

During the neutralization of the sulphuric acid, metal ions hydrolyze and precipitate as hydroxides and hydrous oxides as the basicity of the solution increases (Figure 6). Thus lime treatment to pH 9-10 removes essentially all of the highly toxic contaminants, i.e. heavy metals, radioactive metals, and acidity[2].

The present treatment for radium removal is based on the high insolubility of barium sulphate ($K_{sp} = 8.7 \times 10^{-9}$ @ 18°C)[3], and that radium will coprecipitate with it. This treatment is dependent on the presence of sulphate in the effluent solution, firstly to precipitate barium sulphate when treated with barium chloride, and secondly to keep the precipitate stable so that redissolution will not occur. Thus settling ponds for precipitated sludge must be designed in such a manner that redissolution of the precipitates is not possible, when and if treatment is not required. We have found in our operation that the $Radium_{226}$ concentration can be lowered with the neutralization treatment alone. However, the effectiveness in radium removal appears to be dependent on the amount of calcium sulphate and metal hydroxides and hydrous oxides precipitate that is formed for it to co-precipitate with.

At present we have two lime plants, Pronto and Lacnor-Nordic, treating seepage and runoff solutions for

acidity and metal cations. We are presently using bagged hydrated lime to charge our plants and it is fed to the effluent streams as a slurry from 7000 gallon holding tanks.

We also have two full-time barium chloride treatment plants, Quirke and Lacnor-Nordic, treating for $Radium_{226}$ removal. Bagged barium chloride is dissolved in 500 gallons make-up tanks and fed to the streams by metering pumps. At the Lacnor-Nordic plant we have added the barium chloride with the lime slurry and it is just as effective. One problem here is that the make-up water for the lime slurry contains approximately 1 gram per litre sulphate so excess barium chloride must be added to remove the sulphate and give free barium ions in the treating solution.

Each operating and idle property has presented us with its own unique conditions. A description of these problems and our solutions to them for the seepage and runoff from the various properties follows:

QUIRKE

This mill operated from 1956 to 1960, was shut down until 1968, and is presently operating. The neutralized tailings, pH = 8.5-9.5, during the initial operating period were pumped into a depression called Bud Lake (Figure 7). A small rock dam was constructed to contain the solids with the clarified decant overflowing and discharging into the Serpent River. When operations recommenced in 1968, the original dam was raised and spigotting continued into the original area. At this time, October, 1968, barium chloride treatment was started to treat the clarified decant and seepage solutions from this tailings area.

The limited volume in the original tailings basin had to be expanded to handle future production requirements, and work on a new site was commenced. This new tailings basin and series of dams were designed in accordance with regulatory conditions and in conjunction with governmental departments. The design criteria were to prevent seepage into uncontaminated waters and to direct all effluent through one outlet through various treatment areas and settling ponds. The diversion of fresh water courses from draining into the tailings area and dissolving contaminants was of primary concern as well. This was facilitated by building dams A, B and F (Figure 8) at the outlet of Gravel Pit Lake and digging channels A and B to carry natural drainage towards Dunlop Lake. The original flow was through the new tailings area. The height of the dams will be kept at a level

whereby the ponds and channels in this drainage system will always have a minimum water head of 3 feet over water levels in the adjacent tailings basin. Thus any trans-dam seepage of water will be towards the tailings basin, preventing seepage of contaminated water into the watershed of Dunlop Lake.

Along the south edge of the future tailings area, a water course enters from spring-fed Evans Lake. A dam is to be constructed (Figure 7, Dam K) at the lake outlet to prevent contamination of the lake water. Water levels in this lake are to be maintained at a minimum of 5 feet higher in head than the tailings basin water levels.

At the Main Dam (Figure 9), a spillway has been constructed to carry the clarified decant solution to the treatment area. Here a series of small containment dams and ponds are constructed for treatment and precipitate settling purposes. Dam D is constructed to collect seepage from the main dam with the holding pond to be used as an oxidation area for iron compounds. The outlet through Dam D is the area where the lime slurry treatment can take place if an acidic seepage is developed. Dam G is required to create a settling pond for the gypsum and iron hydroxide precipitate.

The overflow from Dam G then meets the decant from the spillway and the two flows are mixed in the confluent pondage developed by Dam H. The overflow area from Dam H is a weir constructed for agitating the effluent waters as barium chloride addition takes place to ensure good mixing. The pondage below this is the barium-radium sulphate settling area and is backed up by Dam E. Effluent passing Dam E then enters an area backed up by Dam J and is the pondage for collection of recycle water for the milling process when required.

At present there is no decant from this tailings basin. A small volume of seepage from the Main Dam is all that is presently flowing from this area. This seepage is being treated with barium chloride at a rate of 0.0133 lb barium per ton of water.

NORDIC

At present the seepage and runoff from the Lacnor tailings area and the Nordic tailings area are combined into one flow for treatment (Figure 10). However, prior to 1971, this combined effluent did not contain all the Nordic seepage solutions.

Runoff and seepage from the Lacnor tailings area flows down onto the Nordic tailings area. Before

1971, it entered the Nordic runoff and mill effluent pondage. The combined solution then overflowed tailings Dam F by a decant tower, flowed along the base of Dam F, was piped under the fresh water channel system and discharged into Buckles Creek. Barium chloride treatment was carried out at this point and has been utilized since July of 1965. The treated effluent overflowed the small settling area and then discharged into Nordic Lake. The fresh water discharge from Ryan and Frazer lakes was carried via a channel to North Nordic Lake, to Westner Lake, and thence to Horne and Elliot Lakes. Seepage from Dams D and E was controlled and prevented from entering the fresh water system by a lagoon at the base of the dams. This lagoon was periodically pumped out with the solution discharging back on the tailings area.

In the summer of 1971, our Effluent Control program for the Lacnor-Nordic area was revised and the following changes were made:

1. The decant well, and related pondage, on the Nordic tailings was removed.

2. The fresh water drainage from Frazer and Ryan Lakes was diverted down the Buckles Creek system.

3. The runoff and seepage stream from along the base of Dams D, E and F was diverted into the previous fresh water channel and towards North Nordic Lake.

4. Drainage ditches and ponds were dug to handle runoff from the easterly portion of the tailings contained by Dam B. This effluent joins the seepage and runoff from Dams D, E and F before going through the treatment plant and into North Nordic Lake.

5. A lime slurry-barium chloride treatment plant was built at the east end of North Nordic Lake at the point where the combined flows of seepage and runoff enter the lake. The lake is to be used as a settling area.

6. A dam was constructed on the west end of North Nordic Lake to stop effluent discharging into Westner Lake and subsequently to Elliot Lake.

7. The clarified treated water is then pumped from the lake into Buckles Creek. This effluent discharges at a pH of 9.0.

8. A small control dam was constructed on Buckles Creek to prevent particulate matter being carried downstream.

This system has been in operation since September 1971 and on a normal basis worked very effectively. We did encounter some problems during the Spring runoff in that our surge capacity in North Nordic Lake was not adequate in relation to our pumping capacity. Because of the pump capacity problem and also an operating cost factor, a survey is presently being made into the feasibility of driving a tunnel or ditch from North Nordic Lake to Buckles Creek to permit natural drainage.

PRONTO

The Pronto mill operation, from October 1955 to April 1960, was on uranium production. A nearby discovery of copper ore led to the conversion of the mill and the milling of copper concentrate occurred from January 1961 to April 1970. Consequently we have a tailings area composed of two types of tails (Figure 11). This tailings disposal area is within a very small watershed hence very little external runoff from natural areas is encountered. Water storage in the watershed is very limited. Drainage from the tailings area is by two main streams, one from the westerly end of the uranium tailings and the other from the easterly end of the copper tailings. This combined flow enters Pond 2. The main source of contamination comes from the uranium tailings section and determines our treatment system.

In October of 1971, we constructed and brought into operation a lime slurry plant to neutralize the combined Pronto effluent and remove any heavy metals present. A beaver dam in the effluent stream below the plant provides a natural settling area at present. To facilitate an easy and efficient operation at Pronto we are using the Pond 2 area as a surge section and feed water from this pondage to the treatment plant with a number of syphons to give controllable flow rates. Plans are to attempt to stem the seepage through the Pond 2 dam, which was originally built as a roadway, and plug a diamond drill hole which is discharging below the dam. With this seepage eliminated, control of water volume through the plant would be possible. Operating schedules could be developed for the plant, with operating rates being determined by the season rather than by the unpredictable precipitation and runoff conditions. In periods of low precipitation and runoff, mid-winter and mid-summer, the plant could be shut down, thus lowering operating costs.

MILLIKEN AND STANLEIGH

The tailings from both the Milliken and the Stanleigh operations were discharged into the Crotch Lake basin (Figure 12). Originally dams were constructed between the northwest and southeast arms with the tailings being discharged into the northwest arm only. However, operating conditions arose which necessitated the use of the southeast arm and permission from the regulatory agencies was obtained to do so.

There are many possible solutions to rehabilitating these problem areas: however, because of the non-economic return from the expenditure, some balance between reality and perfection must be struck. This is a very important point which must be considered in evaluating suggestions and ideas to be incorporated in the rehabilitation plans and proposals.

The Ministry of Environment requested a submission by us to outline our treatment and rehabilitation plans for this area. In compliance with this request, and in consultation with them, we are presently in the process of surveying and evaluating this sector to prepare this submission.

The finalized submission is not prepared as of the date of writing this paper. However, we are aware of certain conditions which should be considered in the proposal and these are as follows:

1) Isolation of the fresh water in the northeast arm.

2) Diversion of fresh water entering the northwest arm and treatment of the relatively small contaminated flow from the area.

3) Raise the pH of the present body of water in a reasonable time by recirculating it through the treatment plant.

PANEL

The discharge from the Panel Mine was into the Strike Lake basin and was carried on from March 1958 to July 1961 (Figure 13). This area is also under review and our proposal for treatment and rehabilitation is presently being drafted, as requested by the Ministry of the Environment. This submission has also not been finalized at the time of writing this paper.

Some conditions which we must consider in this proposal are as follows:

1) Diversion of contaminated drainage away from Rochester Creek by dams and/or ditching.

2) Flow of contaminated streams to a conveniently located treatment plant and settling area.

3) Location of plant so that a minimum of road and power line construction is required.

ACKNOWLEDGMENT

The authors wish to acknowledge the assistance given by other Company personnel in the execution of the research program and the preparation of this paper; in particular, the assistance of the Idle Mines Group and the Environmental Health Section. The advice and guidance of Mr. C.A. Young and Mr. T.E. Peters, of the Agricultural Department of The International Nickel Company, Copper Cliff, Ontario, is also gratefully acknowledged, as is the assistance of Mr. D.R. Murray, of the Department of Energy, Mines and Resources, and Professors T.H. Heeg, J.D. Winch and D.G. Beauchamp, of the Ontario Agricultural College.

The research described herein has been partially supported by a Research Grant through the I.R.A.P. Program administered by the National Research Council.

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TYPICAL ACID-LEACH
FLOWSHEET
AS USED IN THE
ELLIOT LAKE DISTRICT

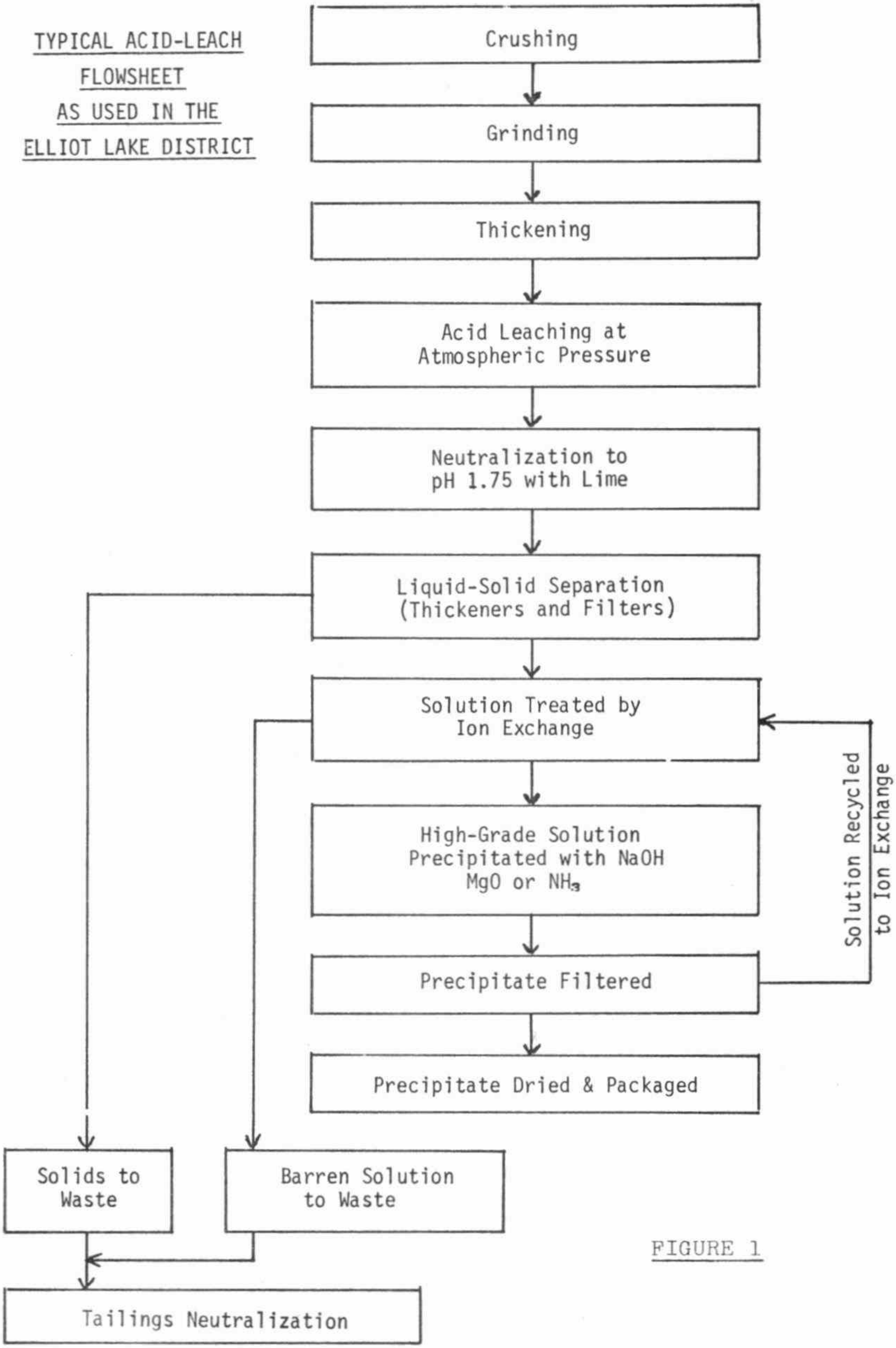
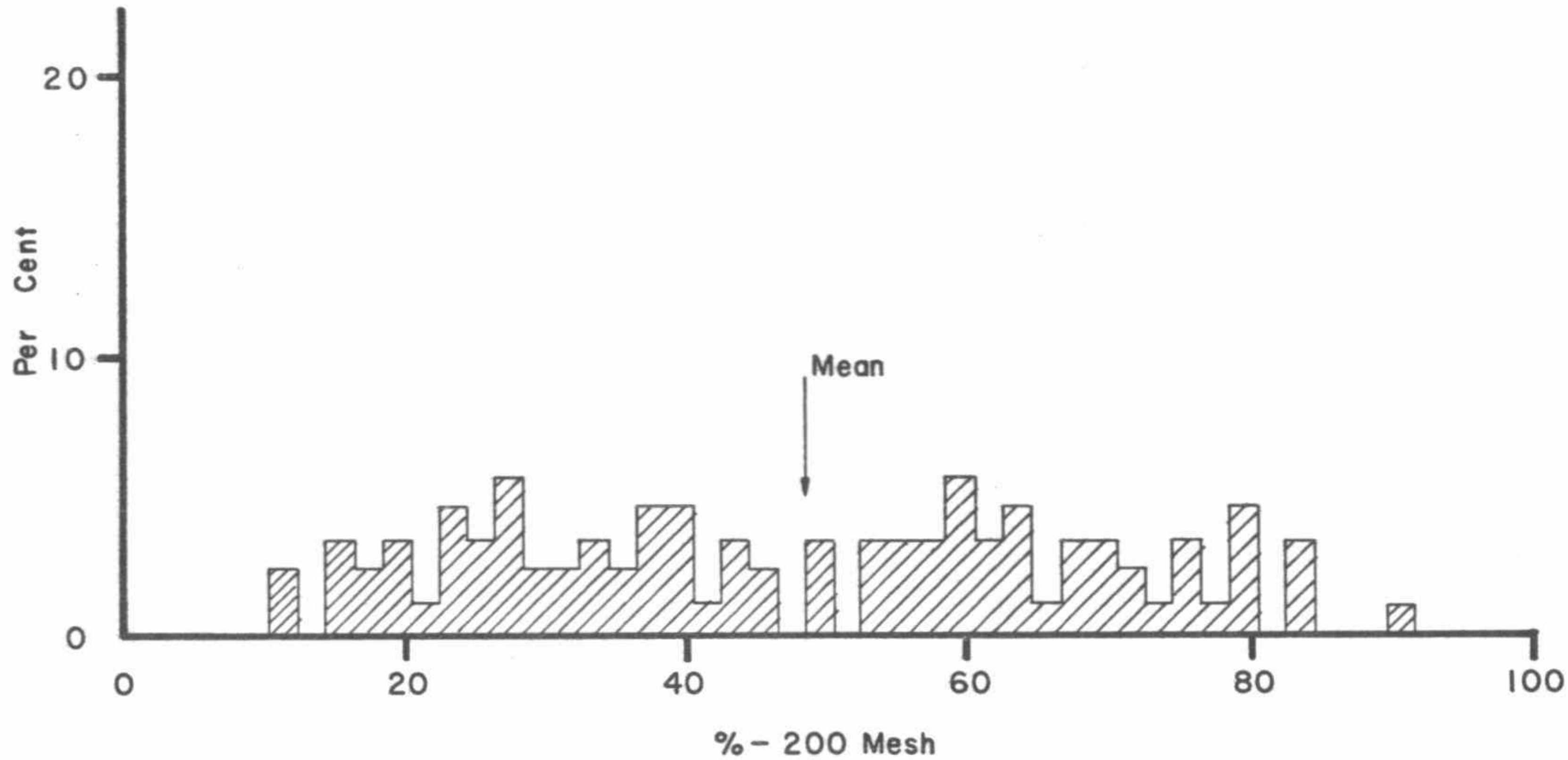
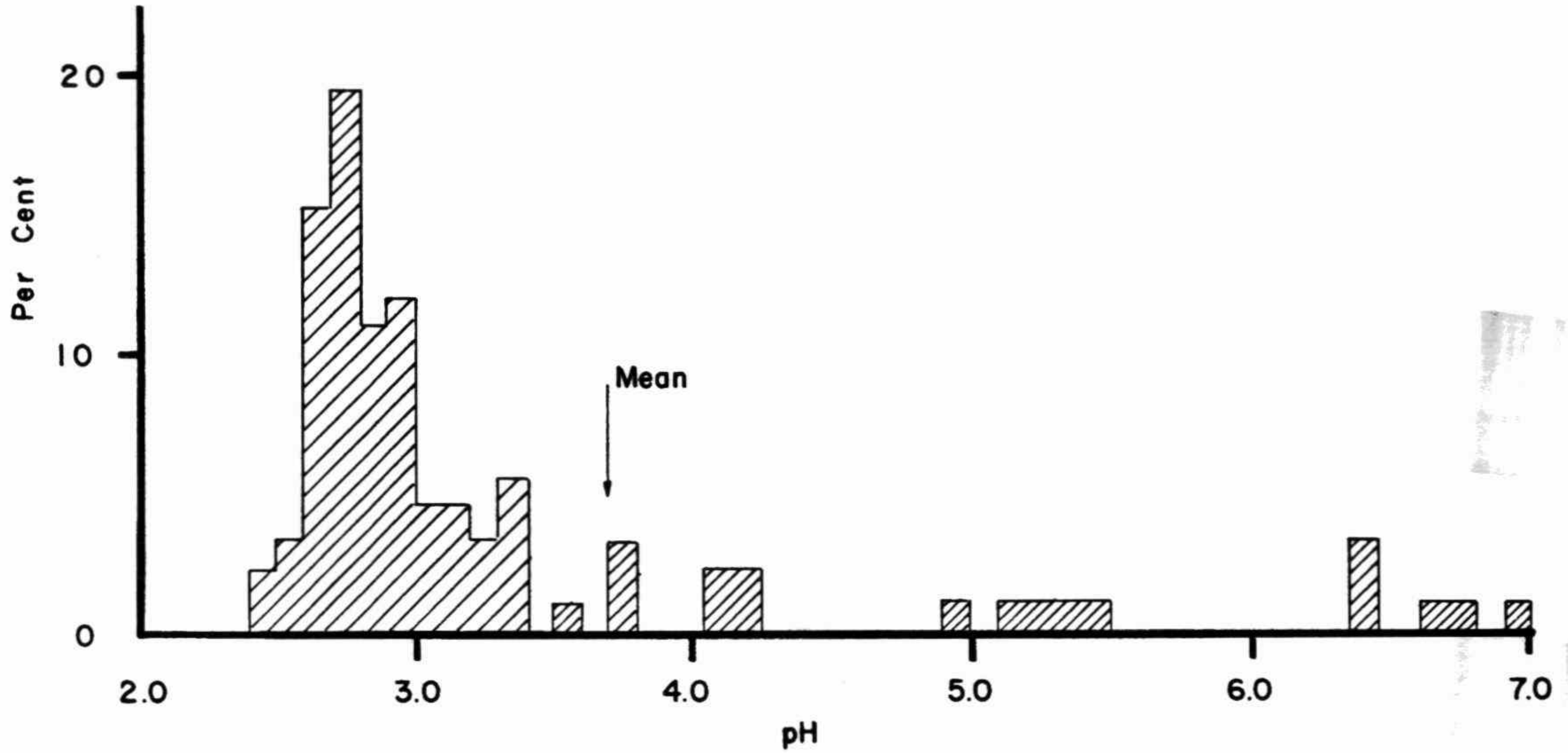


FIGURE 1



PARTICLE SIZE DISTRIBUTION (NORDIC '71)

FIGURE 2



pH DISTRIBUTION (NORDIC '71)

FIGURE 3

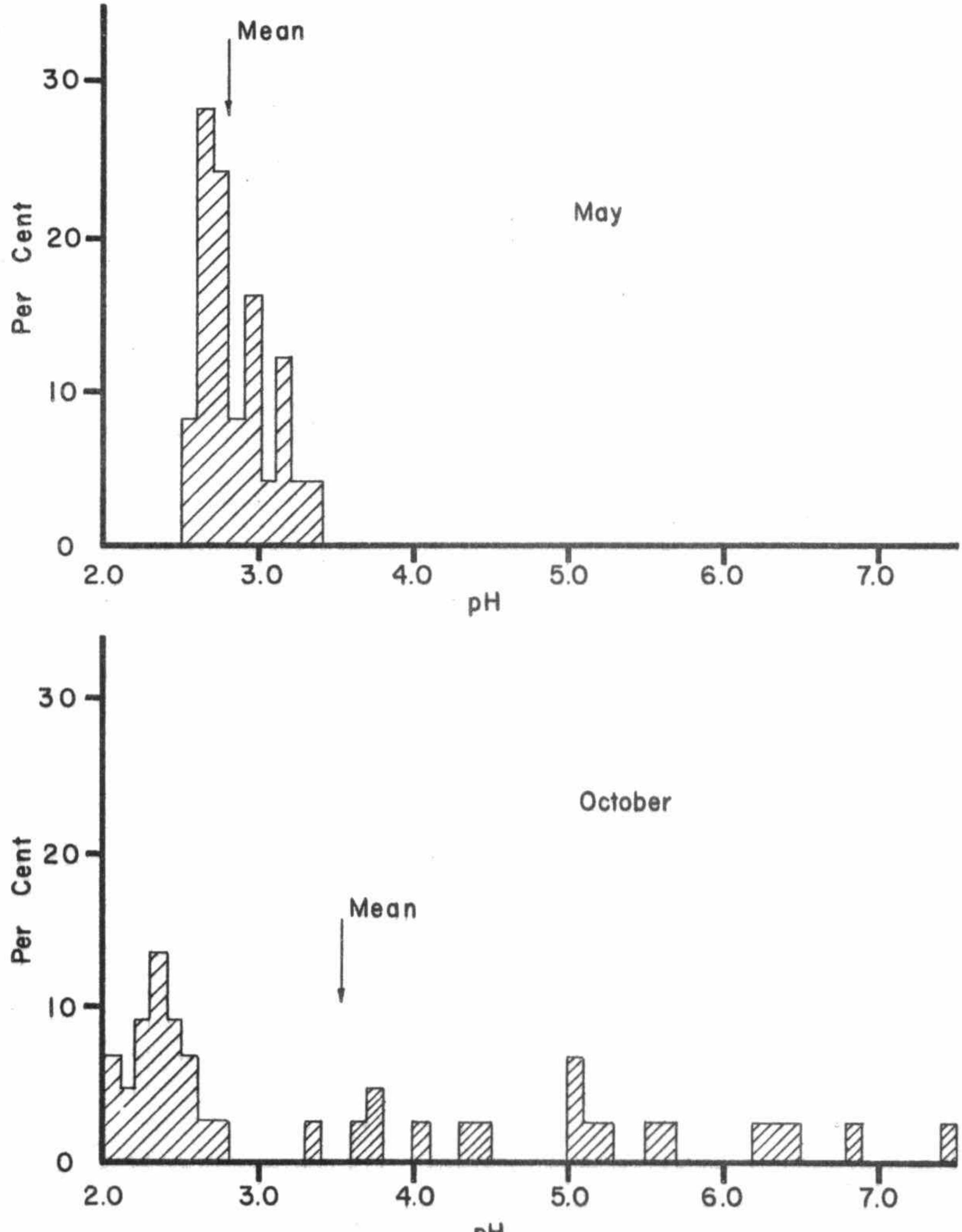


FIGURE 4

pH DISTRIBUTION CHANGE MAY TO OCTOBER (NORDIC'71)

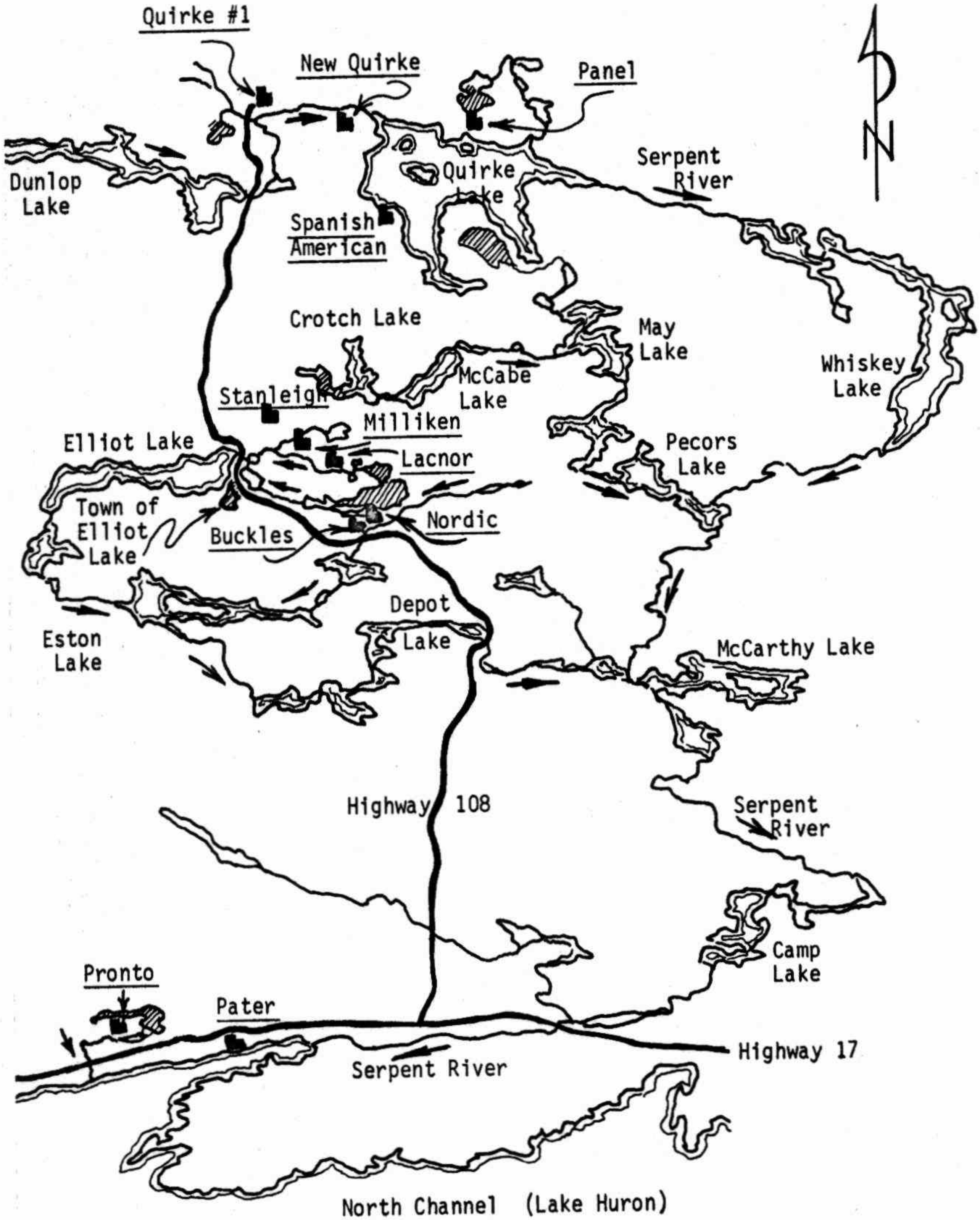


FIGURE 5

THE ELLIOT LAKE AREA SHOWING PROPERTIES OF RIO ALGOM MINES LIMITED

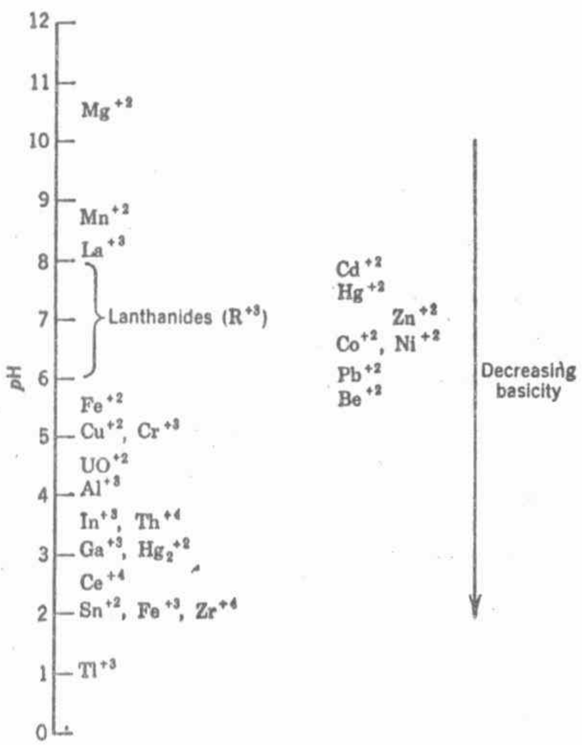


FIGURE 6

BASICITIES OF METAL IONS IN TERMS OF PRECIPITATION pH VALUES FOR HYDROUS OXIDES AND HYDROXIDES

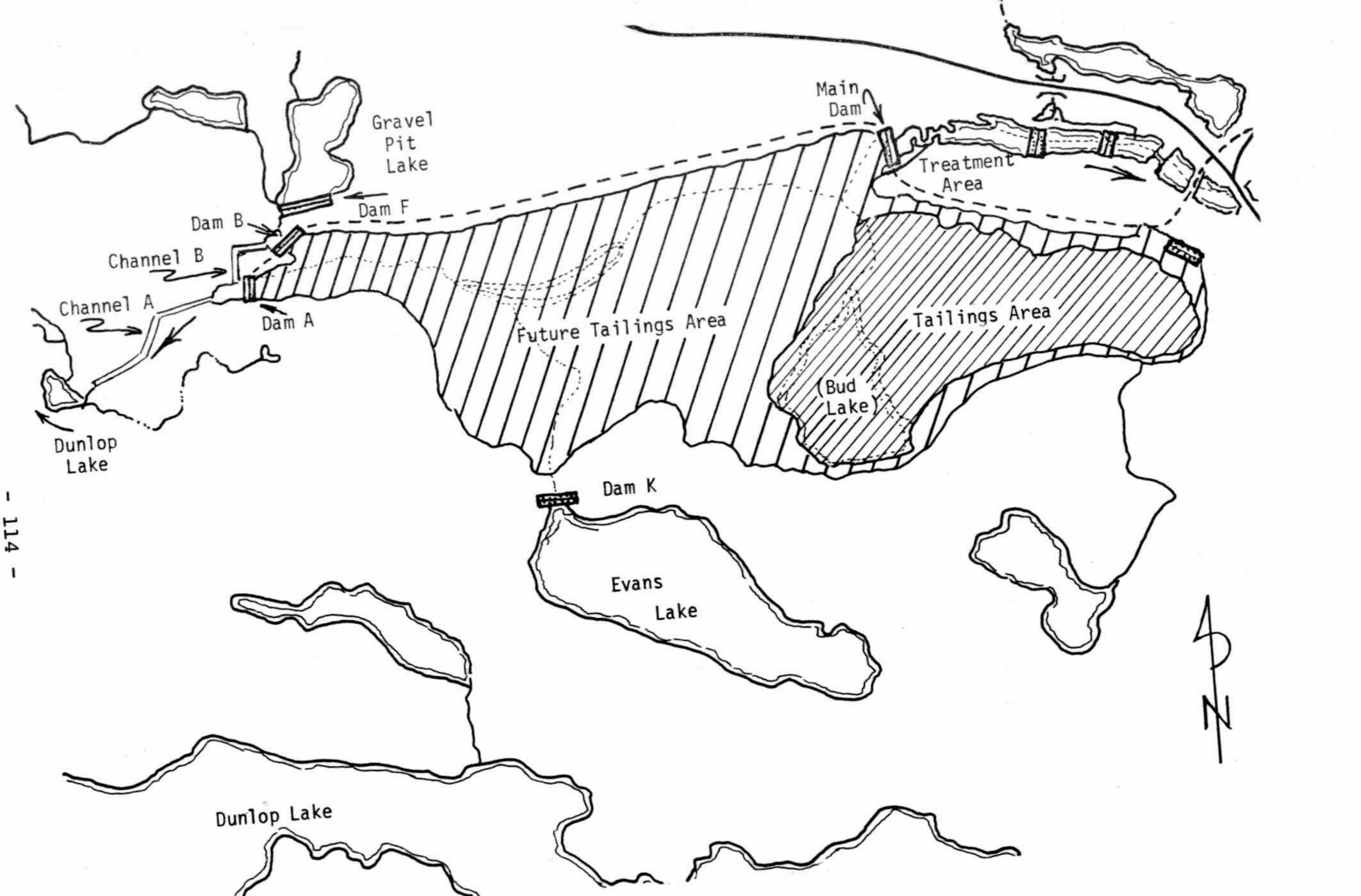


FIGURE 7

QUIRKE TAILINGS AREA: OVERALL

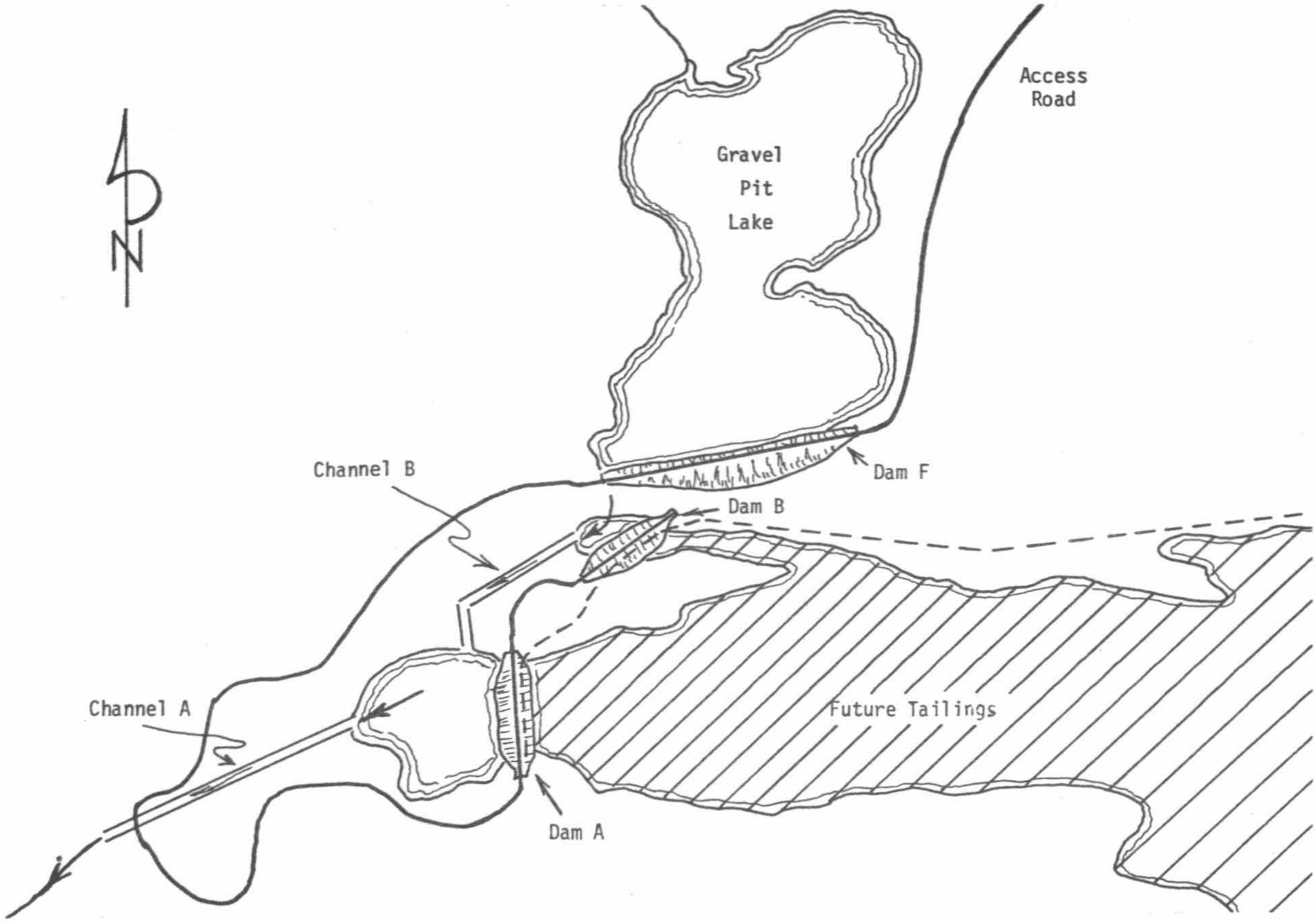


FIGURE 8

QUIRKE TAILINGS AREA: GRAVEL PIT LAKE DIVERSION

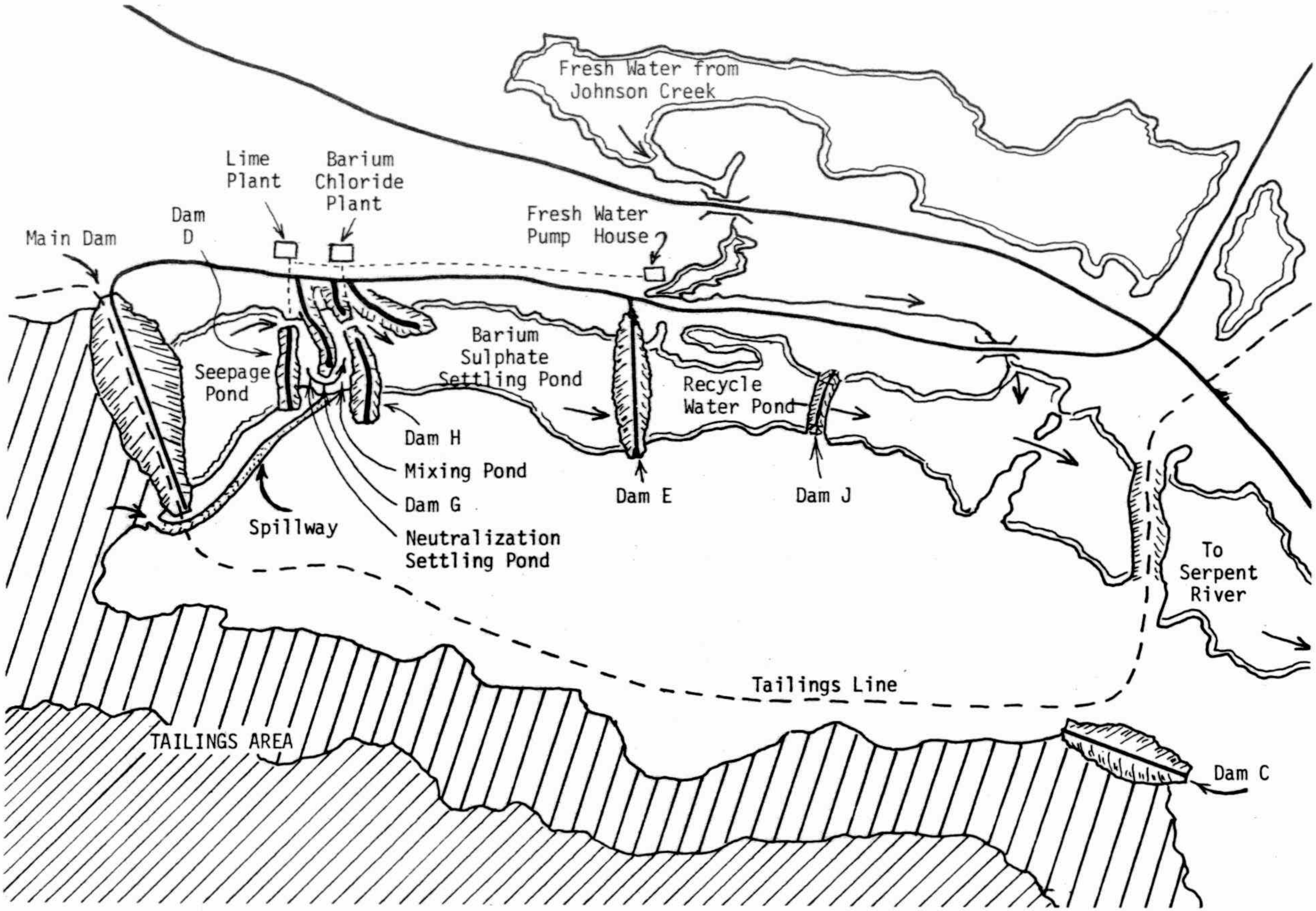


FIGURE 9

QUIRKE TAILINGS AREA: MAIN DAM AND TREATMENT AREAS

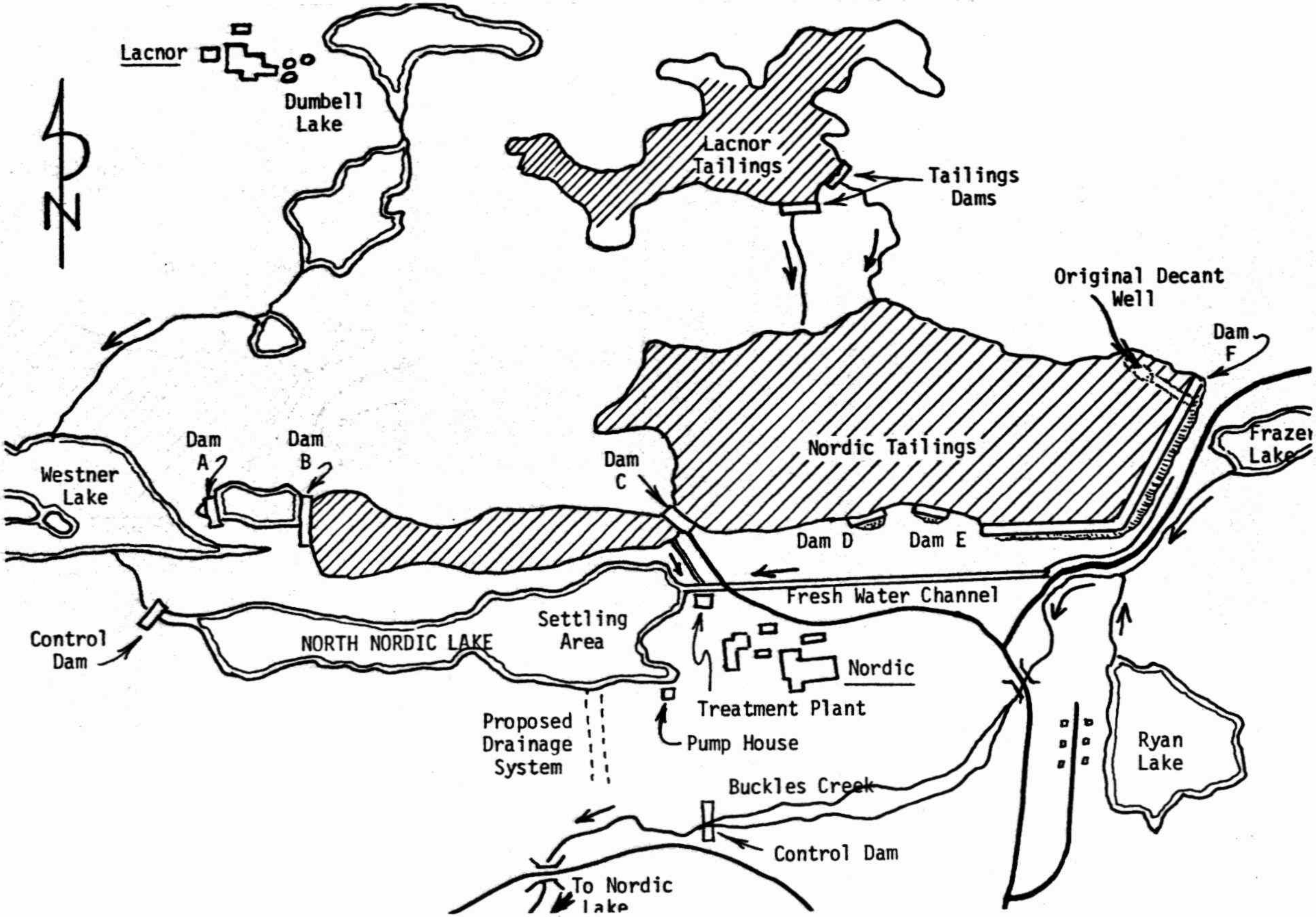


FIGURE 10

NORDIC AND LACNOR PROPERTIES

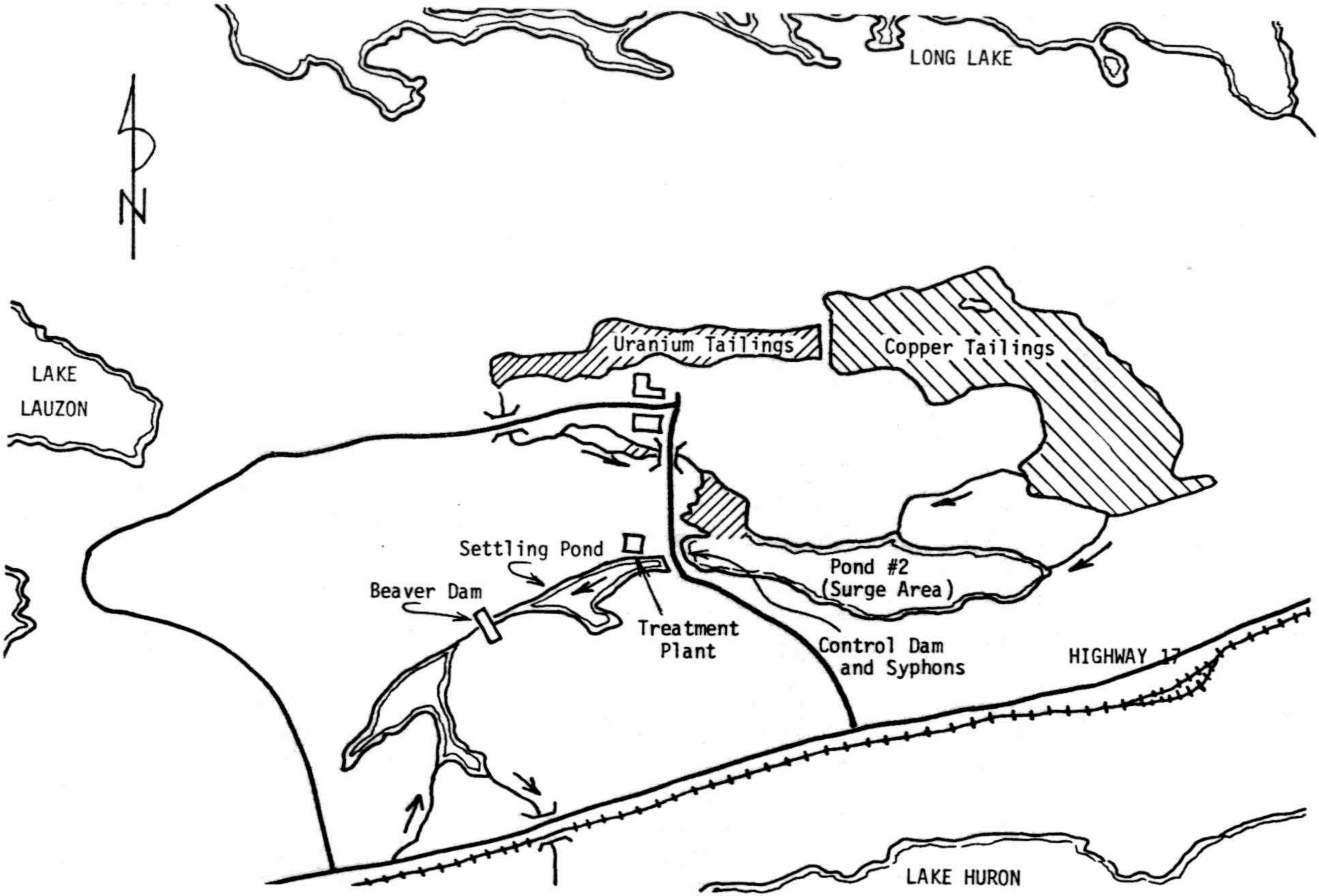


FIGURE 11

PRONTO PROPERTY

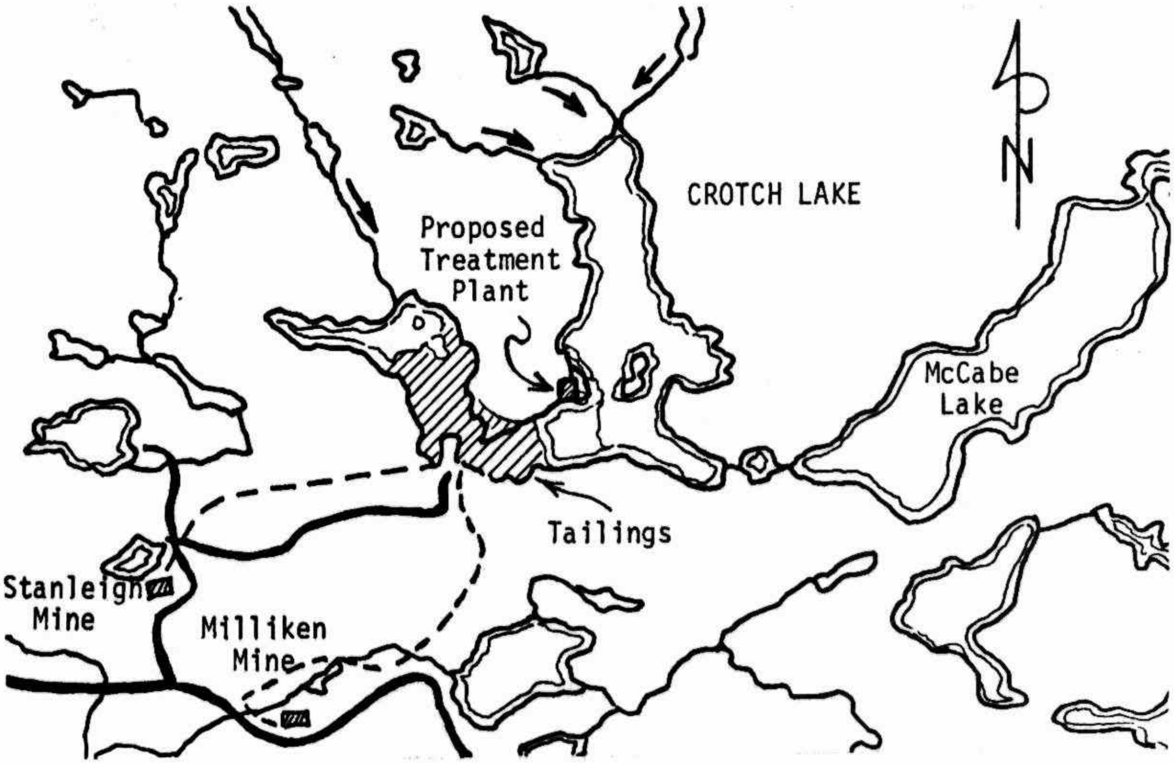


FIGURE 12

STANLEIGH AND MILLIKEN: CROTCH LAKE TAILINGS AREA

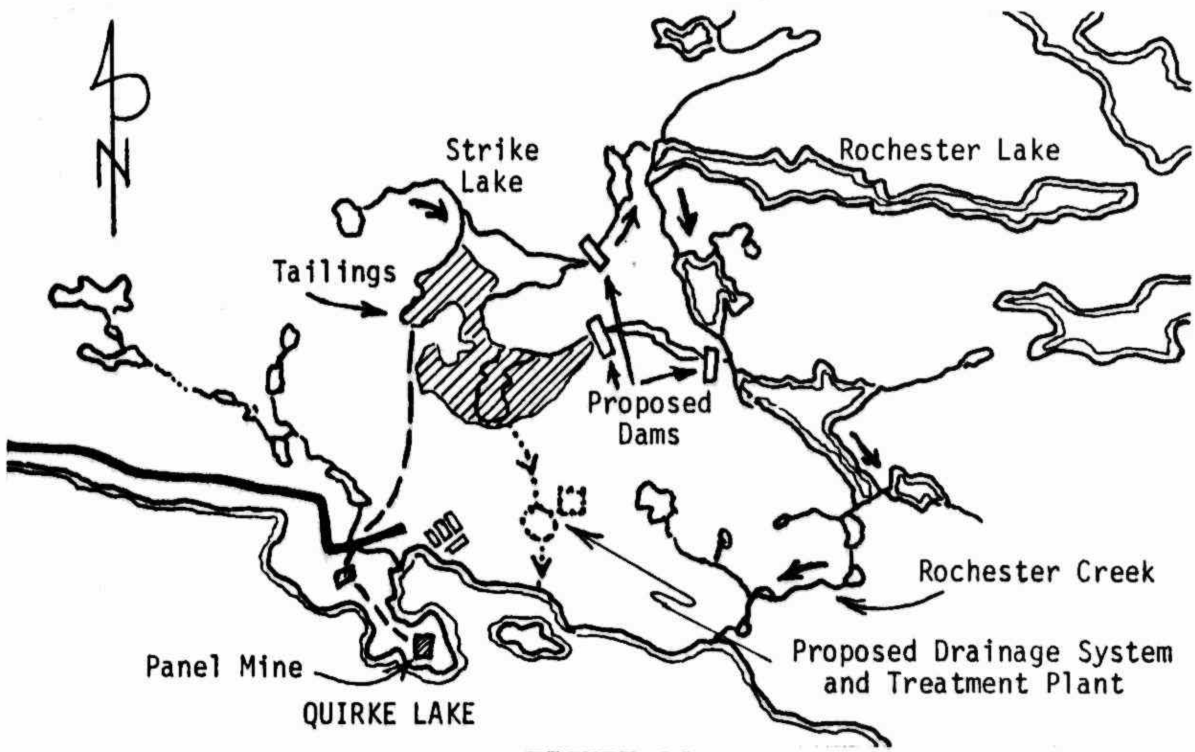


FIGURE 13

PANEL: STRIKE LAKE TAILINGS BASIN

D. I. Mount

PROCEDURES TO ESTABLISH SAFE CONCENTRATIONS OF HEAVY METALS TO FISH AND OTHER AQUATIC BIOTA

BY

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In the copy of the Conference Abstracts that was made available to all conference registrants, it was indicated that Dr. Mount was unable to supply the Conference Committee with a manuscript of his abovenoted paper. We regret the lack of a printed copy of his informative talk in these Proceedings but trust that the following list of references used by Dr. Mount will enable those wishing for more details to obtain them directly from the sources indicated.

Conference Committee.

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RECYCLING TISSUE PLANT EFFLUENT
IN MUSKOKA

BY

R. F. Gropp

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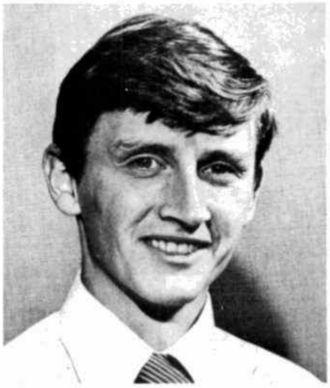
ENGINEERING SERVICES SUPERINTENDENT

and



R. E. Montgomery

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INTRODUCTION

Kimberly-Clark of Canada has built a new Tissue Plant in Muskoka, on the Big East River in the heart of Ontario's cottage country. Since industrial pollution of the waterways would affect the area's tourist income and the area's natural beauty, a dependable method of controlling the plant's discharge had to be found. The O.W.R.C. (now the Ministry of the Environment) carried out hydrological, biological and bacteriological surveys on the river, which is relatively small, having a normal flow of 200 C.F.S., and determined that if the plant discharge did not exceed 500 lb. of BOD_5 per day or 50 ppm of suspended solids the aquatic life in the system would not be affected. As a further all-encompassing condition, the waste water effluent

could not, in the opinion of the Commission, cause unacceptable conditions in the river, such as odour, taste, colour or foam.

These limits were based on future expansion to two tissue machines. The one machine process would use about 2,500,000 U.S. gallons per day of clear water. The effluent from a tissue process normally contains a high level of suspended fiber (organic solids), can contain colour in solution and on the fibers, and can contain dissolved organics, which not only add to the BOD_5 but also cause foam.

It was decided that if the process was designed such that it could make efficient use of fibers and chemicals, a large portion of the effluent could be treated and reused. This philosophy would substantially reduce the quantity of effluent discharged to the river, and could make practical the application of simple treatment processes prior to discharge. The plant was designed for a minimum recycle rate of 80 percent, with 100 percent recycle possible, for short periods of time.

The block diagram in Figure 1 shows the water flows for the total process. The clarified effluent from the tissue process is returned to the water plant where it is mixed with up to 20 percent fresh water from the river. A water bleed equivalent to the makeup minus the losses, mainly evaporation, is treated and sent back to the groundwater and/or the river. To date, we have been able to recycle more than 80 percent of the clarified effluent and have stayed well within the Commission's effluent limits. This paper will describe the system, some of our operating methods and the results that we have been able to obtain.

This plant is the first entirely new operating site for the paper industry in Ontario in 25 years. Kimberly-Clark in Huntsville was the winner of the A.V. Delaporte award in 1971 for large plant achievement in industrial waste control in Canada.

Water Use in The Tissue Process

To make one ton of paper, approximately 350,000 U.S. gallons of water of various clarities are used. Our process uses approximately 25,000 U.S. gallons/ton of clean (fresh) water, and 32,000 U.S. gallons/ton of water which is free

from suspended solids. The remaining water, used to form the sheet, can and does have high suspended solids load. To maintain this relatively low fresh water consumption, a large disc type saveall filter is used to filter process water to 10 ppm suspended solids and recover the fiber fines. This water can then be reused in the parts of the process where only clarity is important. The saveall is large enough to filter out the fines in the excess process water before it leaves for the water and effluent plant. This not only allows for reuse of the fines but substantially reduces the hydraulic and solids load on the water and effluent plant.

As further refinements, all of the chests are designed with sloping bottoms to reduce fiber losses during grade changes; the stock rejects are thickened by a reject screen and handled as solid waste; dye and chemical spills are collected in a special series of drains for separate disposal. They are not allowed to trickle into the main process effluent.

Sloppy operating procedures are not tolerable in a plant that is attempting to recycle effluent. All of the spills, excess stock losses etc. can come back to haunt the tissue process if the purification capacity of the water plant is exceeded.

The Water Treatment Plant

The water treatment phase of the process used at Huntsville is shown schematically in Figure 2. This Kimberly-Clark patented process was developed in our Fullerton, California Mill primarily to reduce consumption, due to the scarcity of water in the area. The process makes use of the fact that the application of excess lime precipitates magnesium hydroxide from water regardless of whether the magnesium is present as carbonate, bicarbonate, sulphate or chloride. When the positively charged magnesium comes out of solution, it is very effective in coagulating and precipitating the negatively charged fiber debris. Also, the presence of lime in excessive quantities has sorptive capacity for dissolved organics.

All of the process effluent is collected in the plant "U" drain system and screened in a vertical trash screen on a ¼" x ¼"

mesh. After screening the water is pumped from the effluent sump to a 100 foot diameter effluent clarifier, where the settlable solids are removed. This unit also acts as a surge chamber to take wash-up water and grade change water when process water consumption is low. This surge can amount to 200,000 U.S. gallons. The solids are pumped to the sludge handling system and up to 20 percent of the clarified water is bled off for subsequent treatment before being discharged to the river. An equivalent amount of river water for make up is mixed with the remaining 80 percent of the clarified water for treatment. After thorough mixing a small portion of the main flow is bled off and fed to the magnesium oxide reactor, where the magnesium oxide reacts with the bicarbonates in the water and scrubbed flue gas to form soluble magnesium carbonate and magnesium bicarbonate. The water from the reaction is then reintroduced into the full flow with a resultant magnesium concentration of approximately 35 ppm expressed as calcium carbonate.

Calcium oxide is then dissolved and metered into the system as a function of flow but trimmed through a pneumatic computer by a pH signal which is proportional to the pH of the resultant flow. After introduction of the lime the pH is approximately 10.8. Coagulant aids are then metered into the system at a rate proportional to the total flow to maintain a 1/2 ppm level.

After thorough mixing in separate basins, the magnesium comes out of solution as magnesium hydroxide encompassing the suspended solids. The resultant flow is then agitated in the floc basin for a minimum of 20 minutes where the floc is allowed to grow in size and weight. Coagulant aids help the primary flocculant by electrical attraction and mechanical bridging.

Dissolved organics such as dye are also absorbed and/or adsorbed at this point by the magnesium hydroxide and lime.

After the reactions take place in the flocculating basin, the water is syphoned out of the basin and fed to the excess lime clarifier for solids removal. A portion of the sludge from the excess lime clarifier is returned to the lime mix basin to stabilize the softening and precipitating reaction and the remainder of the sludge is sent to the sludge handling system.

The clarified water from the excess lime clarifier contains calcium hydroxide, magnesium hydroxide and calcium carbonate in solution. This water is sent to a 45 foot diameter Eimco reactor clarifier, called the solids contact stabilization reactor clarifier. Scrubbed flue gas (carbon dioxide) is added to the reaction zone which, as a first step, converts the hydroxides to their respective carbonates. The calcium carbonate is in supersaturated solution. Sludge, produced in the unit, is recirculated back into the reaction zone, to maintain a high solids level and this, coupled with agitation, creates the contact necessary to stabilize or reduce the calcium carbonate back to its saturation level. This is done with the intent of forming the precipitate on previously precipitated calcium carbonate particles which should have a relatively pure surface available to promote crystal growth. Polyelectrolite is also added to the reaction zone at a rate of 1.5 ppm to improve settling and resultant water clarity.

This unit is designed with both a variable speed rake and reaction zone impeller to control reaction zone solids and total particle contact. We are operating the unit at a pH of 10.2 or slightly greater. This is controlled by the rate of scrubbed flue gas addition (carbon dioxide) into the reaction zone. The overflow from the solids contact stabilization reactor clarifier is then fed to a recarbonation tank.

Scrubbed flue gas (carbon dioxide) is introduced into the bottom of the tank by diffusers and the pH is reduced from 10.2 to 7.5. In the recarbonation process, residual carbonates are dissolved and the primary flocculant, (magnesium hydroxide), if it carries over, is also dissolved. As a final step, the water is filtered in a 4 cell sand filter. This provides a final polish to the product and is intended to handle short term clarification upsets that occur upstream in the process. The filter is equipped with automatic backwash which is returned to the effluent clarifier for retreatment.

The filtered flow is fed to a 300,000 gallon clearwell which provides water for the tissue process. The clearwell also provides surge capacity for the variable process demands, filter backwash, and short downs in the water plant, as well as supplying some fire protection water for the plant.

Treatment of The Effluent Clarifier Bleed

As previously stated, we have made provisions to bleed off a small percentage of the effluent clarifier overflow (approximately 20%). Based on our experience this flow can be treated and disposed of and stay within the limits that were laid down by government regulations.

Referring to Figure 3, the bleed overflows from the clarifier to two polishing basins in parallel that are lined with a Hypalon liner. These basins are 400 feet long, and 100 feet wide, and have a normal operating depth of 5 feet. The total capacity is over 5 million gallons. The flow is distributed across the width at the inlet end, and this, coupled with the shape, tends to reduce channelling and possible septic spots. At a 20% bleed rate, there is up to five days retention in the basins, to allow the settling of solids, and reduce the temperature and increase the oxygen level in the water. The basin is constructed such, that in the event of an upset, the outlets can be closed off and the flow retained at a 20% bleed rate for an additional five days. This will allow time to rectify the problems and bleed the water into the next stage at a rate that will not exceed the limits set for the river. These basins also supply water for fire protection on the property.

Water that is discharged from the polishing basins drops down a 30 foot embankment in an aerating tube, to a two cell percolating bed. The two one-acre cells consist of dyked areas, that have been filled to a depth of 5 feet with a relatively coarse sand. At the 5 foot depth, a tile bed has been installed. The bottom of the beds are not sealed, and the groundwater table has a midsummer level of 10 feet below the top of the bed. In operation, the bed is flooded to a depth of 12 inches to 18 inches, the flow is then switched, and the water is then allowed to percolate through the sand. The trapped air bubbles back through the sand and effluent to the surface. After the water has visibly left the surface, and as it moves vertically downward through the sand, it pulls air into the interstices behind it, recharging the bed with a new supply of fresh air. The drainage tile was installed to cope with the close proximity of the water table and the high resistance to horizontal water flow. Some of the water will escape to the water table (about 30%) and the remainder will be picked up by the drainage tile and distributed on the river bottom via a foam trap. The above

conditions (alternately wet and dry) coupled with the large surface area of the sand, create an ideal environment for the growth of bacteria, which in turn consumes the dissolved wastes in the effluent and reduces the oxygen demand. The percolation beds were installed as an extra precaution during the summer months as further insurance against such "intangibles" as taste, odour etc. It was a pleasant surprise to discover that the percolation beds could in fact be used all year round without freezing and still accomplish the high degree of purification which was observed during the summer months.

Sludge

Referring to Figure 4, sludge is removed at the effluent clarifier (fiber waste) and the excess lime clarifier (magnesium hydroxide and calcium carbonate). We have a very low freeness sludge, because of the tissue process design and the nature of the excess lime clarifier sludge. To reduce the freeness variability, the sludges are pumped to a sludge blending chest prior to being thickened on a vacuum belt thickener. After thickening, the mat is shredded and dumped into a dump truck for disposal. The thickened sludge consistency is between 30% and 50%. The sludge has a relatively high pH and used at the municipal dump as a garbage cover. The sludge is typically 1/3 fiber and 2/3 calcium carbonate on a dry basis. About 10 cubic yards are generated daily. At present, the filtrate is returned to the effluent clarifier, but we have plans to bubble carbon dioxide through the sludge and revert the magnesium hydroxide back to soluble magnesium carbonate to reduce the magnesium oxide consumption. It would also be possible to recover the lime if the sludge could be burnt in a lime kiln. The lime consumption in this process is too small to recover economically.

Waste dyes and dye spills are collected in a separate "U" drain system. These fiber substantive dyes are fed into the sludge blending chest where solids are high and available dye sites are plentiful. When the sludge is filtered, the filtrate which is returned to the water process, is free of colour. The dye, firmly attached to the sludge, is sent to the disposal site where, in time, it will break down with the fibers. Tests have shown that once the dyes are attached to the fiber they are not washed out by rain water.

Safeguards

The plant operates 24 hours per day, 7 days per week. To cope with equipment breakdowns and human error, many safeguards were built into the effluent process. This was done to ensure that the quality and quantity of our effluent is unaffected by process upsets. Each piece of equipment in the process could drop out for maintenance or repair and succeeding equipment or alternative systems could still take care of the process demands. As a further safeguard the level in the polishing basins can be increased by 2.5 million gallons. The decision to valve off the polishing basin outlet could be made as a result of the T.V. camera monitoring the river at the discharge, or a colour situation or a turbidity situation in the flow to the polishing basins. Colour and turbidity are monitored continuously in the lab and an alarm is sounded when they exceed empirical limits that we have set. Even though they could be bypassed without serious consequence, the perc beds -our final line of defence- are the final insurance against polluting the Big East River. To date, they have coped with all of the small problems that have appeared.

OPERATING DATA

Suspended Solids

Suspended solids are removed in:

(1) Saveall Disc Filter
(2) Effluent Clarifier
(3) Polishing Basins
(4) Percolating Beds.

Extensive data was collected during October and November 1971 to determine the effectiveness of the saveall filter. Water filtered on the saveall and which would otherwise have entered the effluent system contains approximately 625 ppm suspended solids. Eventual discharge to the effluent clarifier (See Figure 5) contains about 150 ppm. Some of this 150 ppm originates from accidental spills, etc. which cannot be directed through the saveall, so the reduction in this filter is more than 475 ppm.

The average daily suspended solids load to the effluent clarifier is 150 ppm. Previous data indicates that 35 ppm suspended solids overflow from the clarifier. The suspended solids reduction is therefore 115 ppm.

Normally 13 percent of the effluent clarifier overflow is directed to the polishing basins. The original design of the effluent system has provided a safeguard against effluent clarifier upsets, by allowing short term discharge of clearwell water (suspended solids = 0), instead of effluent clarifier overflow which may be high in suspended solids, COD or colour. The average load of suspended solids to the polishing basins is 20 ppm, 8 ppm suspended solids escape to the percolation beds. The reduction of solids in the polishing basins is therefore 12 ppm. The suspended solids reduction in the percolation beds is about 9 ppm leaving 3 ppm discharged to the Big East River. The entire effluent system is responsible for a reduction in suspended solids from 625 to 3 ppm.

Oxygen Demanding Substances

BOD_5 is the traditional indicator of oxygen demand. At Kimberly-Clark in Huntsville the water plant operator has the ability to vary the recycle rate, discharge rate, source of discharge, retention time in effluent clarifier and polishing basins. It is therefore, quite important that he is aware of the oxygen demand through the water and effluent treatment systems, on a day to day basis. The decision was therefore made to use COD as an indicator of oxygen demand as well as the daily control test.

Tests indicate the correlation between COD and BOD has been -

$$20 > \frac{COD}{BOD_5} > 6$$

for the first year after startup.

The average COD entering and leaving the effluent clarifier is 2,350 lbs/day and 1,615 lbs/day respectively. Because over 80% of the effluent clarifier overflow is recycled, only 175 lbs/day COD enter the polishing basin.

The COD reduction in the polishing basin is from 175 lbs/day to 125 lbs/day. In the percolation beds it is from 125 lbs/day to 50 lbs/day. In the water treatment plant the overall COD reduction is from 1480 lbs/day to 1180 lbs/day. This is due to the lime and magnesium purification.

Temperature and Slime

Although the operator can recycle 100 percent of the effluent clarifier overflow for sustained periods of time, the average recycle rate to date has been 87 percent. At plant startup the system was completely closed for two months, allowing no discharge water. The result was high temperatures in the process water and a tremendous slime build-up. At present the recycle rate is determined in part, such that temperature and slime build-up are at tolerable levels. Referring to Figure 7, the effluent clarifier and polishing basins are responsible for lowering the effluent temperature substantially, and during the first year's operation the discharge effluent to the river has never exceeded the river temperature by over 10 Fahrenheit degrees.

In order to put this in proper perspective, the average discharge is 140 U.S.G.P.M., and the average East River flow is 200 C.F.S. Using the most severe temperature conditions, if the discharged effluent was 50°F and if the river was 40°F, the resultant river temperature would not rise by 1/50 of a Fahrenheit degree.

Colour Removal

The majority of the paper dyes we have selected are fiber substantive and therefore are attached electrically to the fibers. The effluent clarifier removes much of the colour by settling the fibers. There have been periods of high "free" dye in the water and this situation is handled by using a 100 percent recycle rate until the colour in the clarifier improves.

The water control lab is equipped with two sight glasses to continually display the colour of water going to and coming from the effluent clarifier.

It has been shown that the percolation beds are capable of converting water with a slight yellow tinge (as is the Big East River) to a completely colourless effluent.

The water treatment plant removes large amounts of colour by the sorption of the free dye on the freshly precipitated calcium carbonate and magnesium hydroxide. This is necessary during periods of high recycle colour and also to strip the natural yellow colour of the Big East River water.

Conclusion

Based on the operation of the system to date the following conclusions can be made:

(1) The saveall filter has met all our expectations and has proven that such a filter can handle all process flows.

(2) The excess lime process has permitted high recycle rates which yield low effluent volumes.

(3) The percolation beds have yielded significant reductions in both COD and suspended solids and have proven capable of winter operation.

To date the results obtained have been most gratifying. As only one machine is currently involved we had set our own maximum limits at half of the approved quantities, i.e., 250 lbs BOD_5 and 25 ppm suspended solids. In practice, our control is based on COD and results are well below the above figures. There are two keys to the satisfactory operation of the system.

FIRST: - a new well-integrated system designed to minimize waste with sufficient safeguards to allow for some human errors, process upsets and equipment failures.

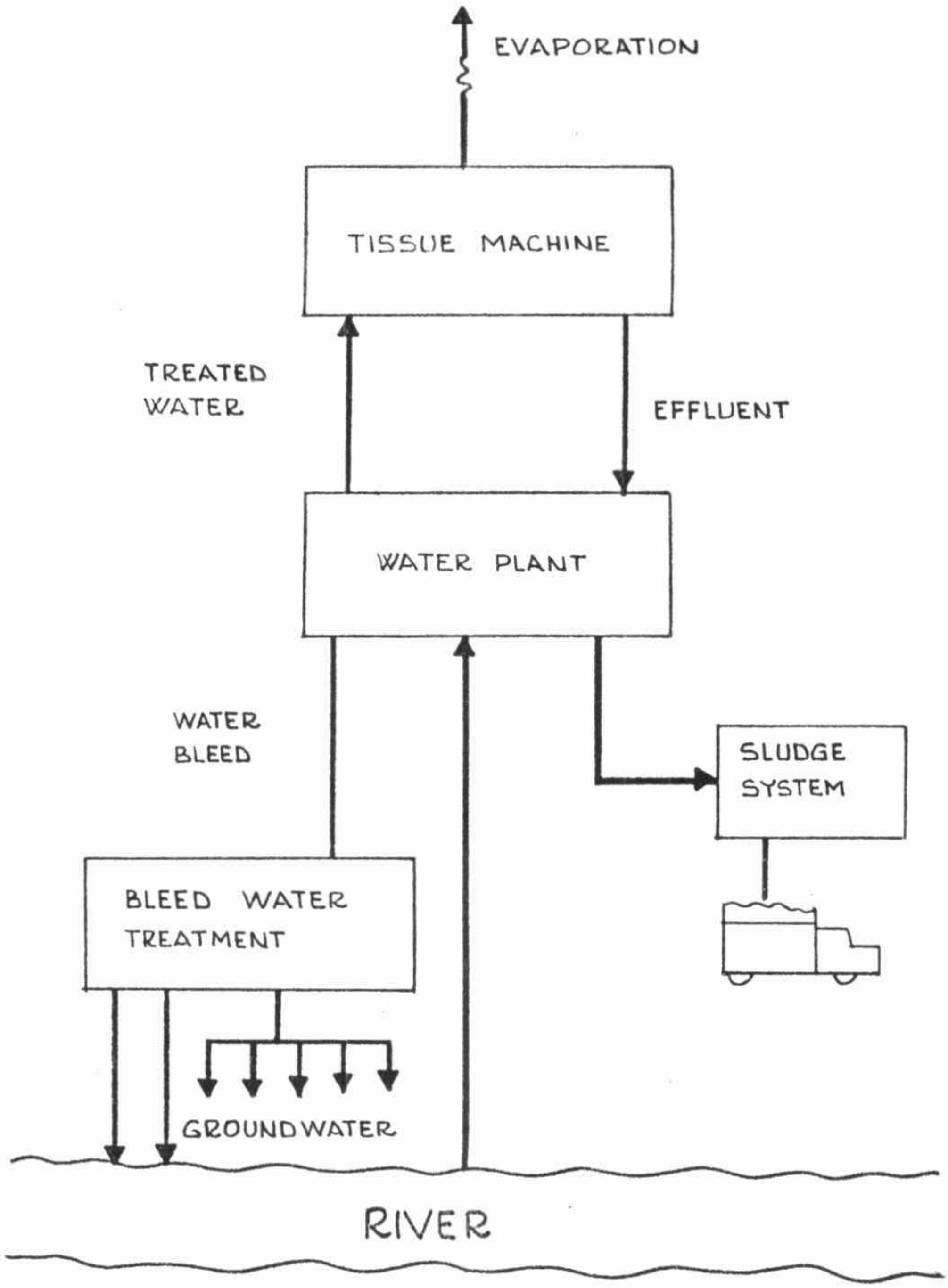
SECOND: - and probably most important, a total commitment by all plant personnel to not pollute our scenic region.

References

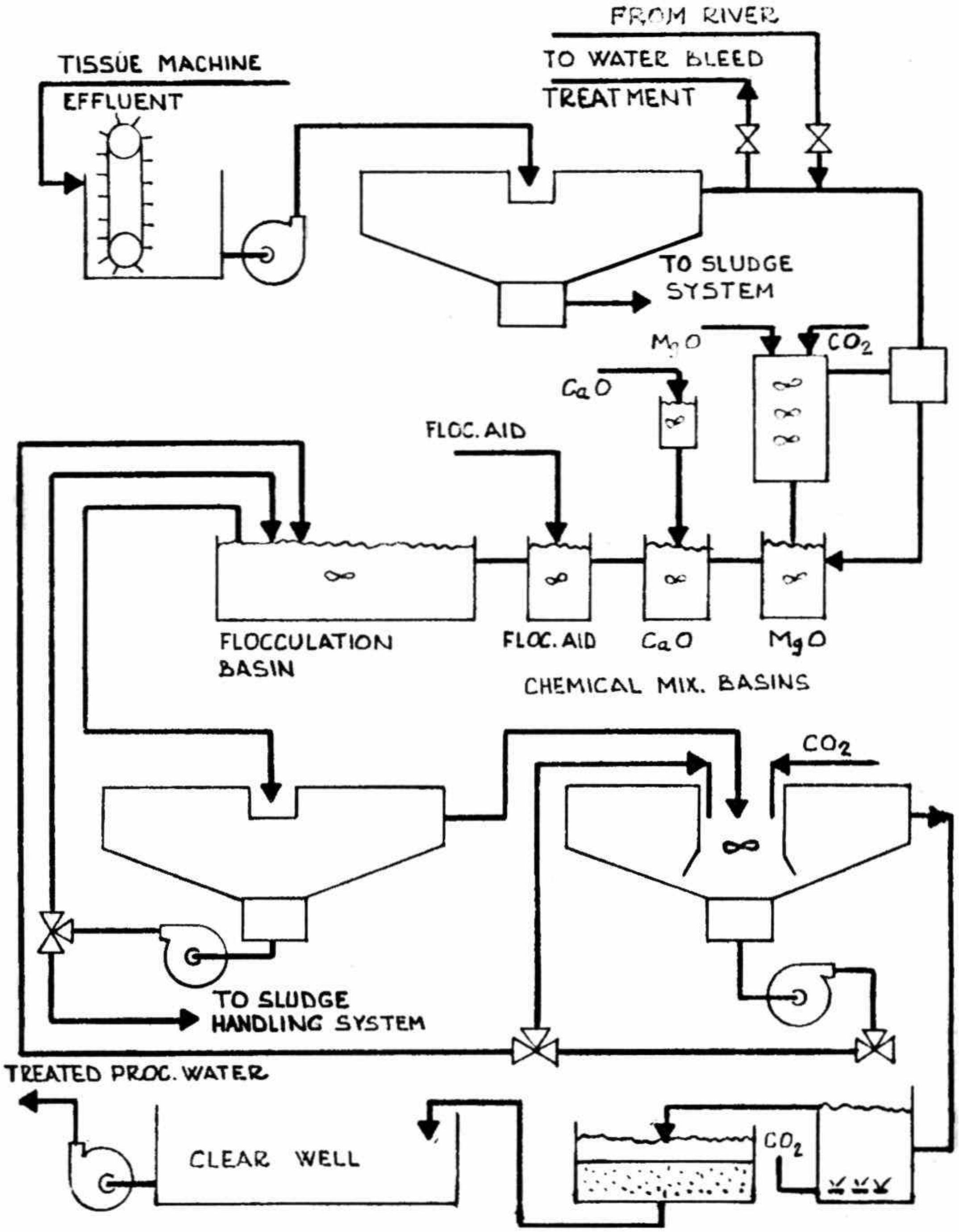
1. Canadian Patent - No. 803,576

2. A.R. LeCompte - Water Reclamation by Excess Lime Treatment of Effluent - Tappi Dec./66 Vol. 49, No.12

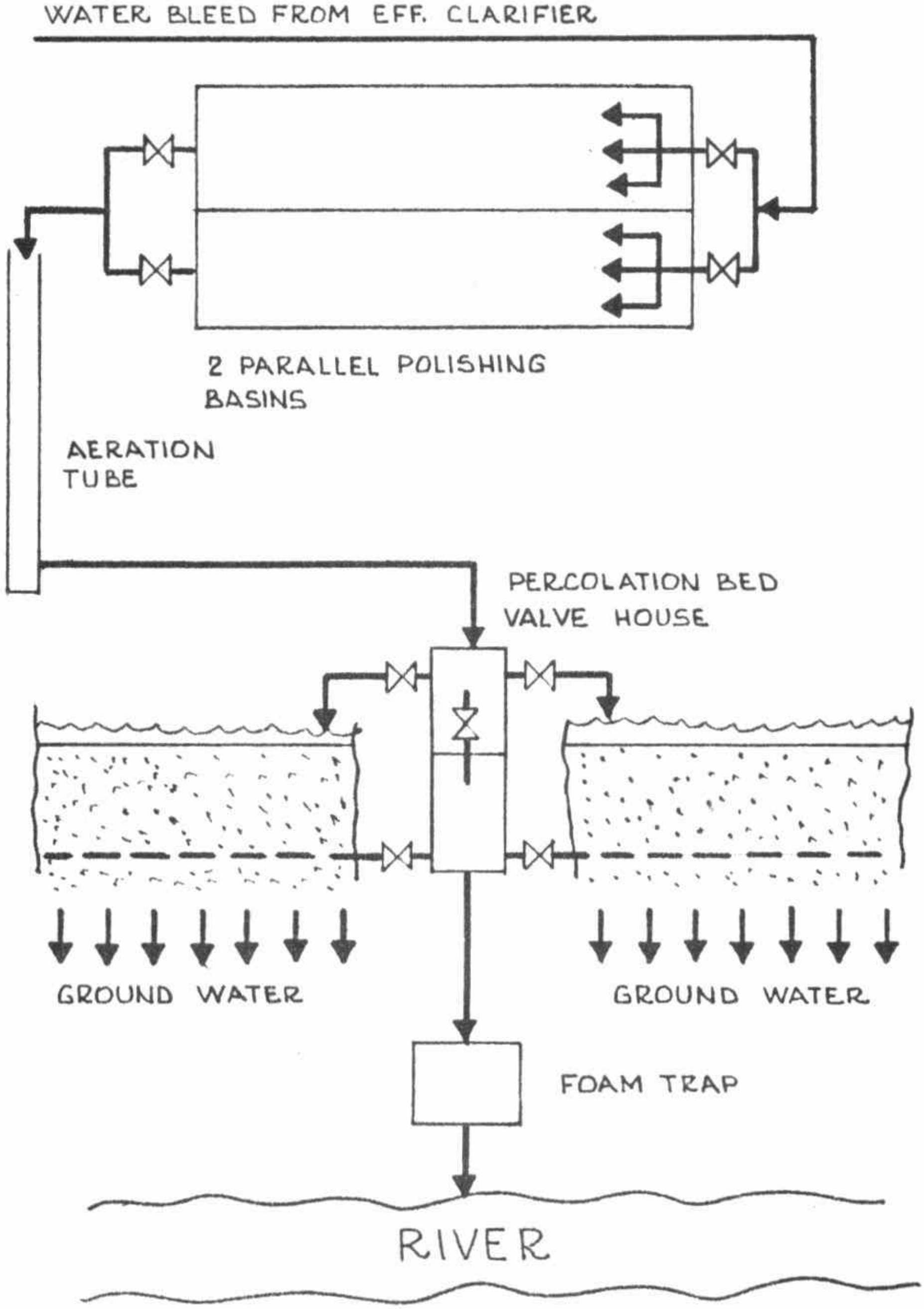
3. R.F. Gropp - Pollution Control by Recycling Effluent - presented at the 6th Air & Stream Improvement Conference, April 13-15, 1971.



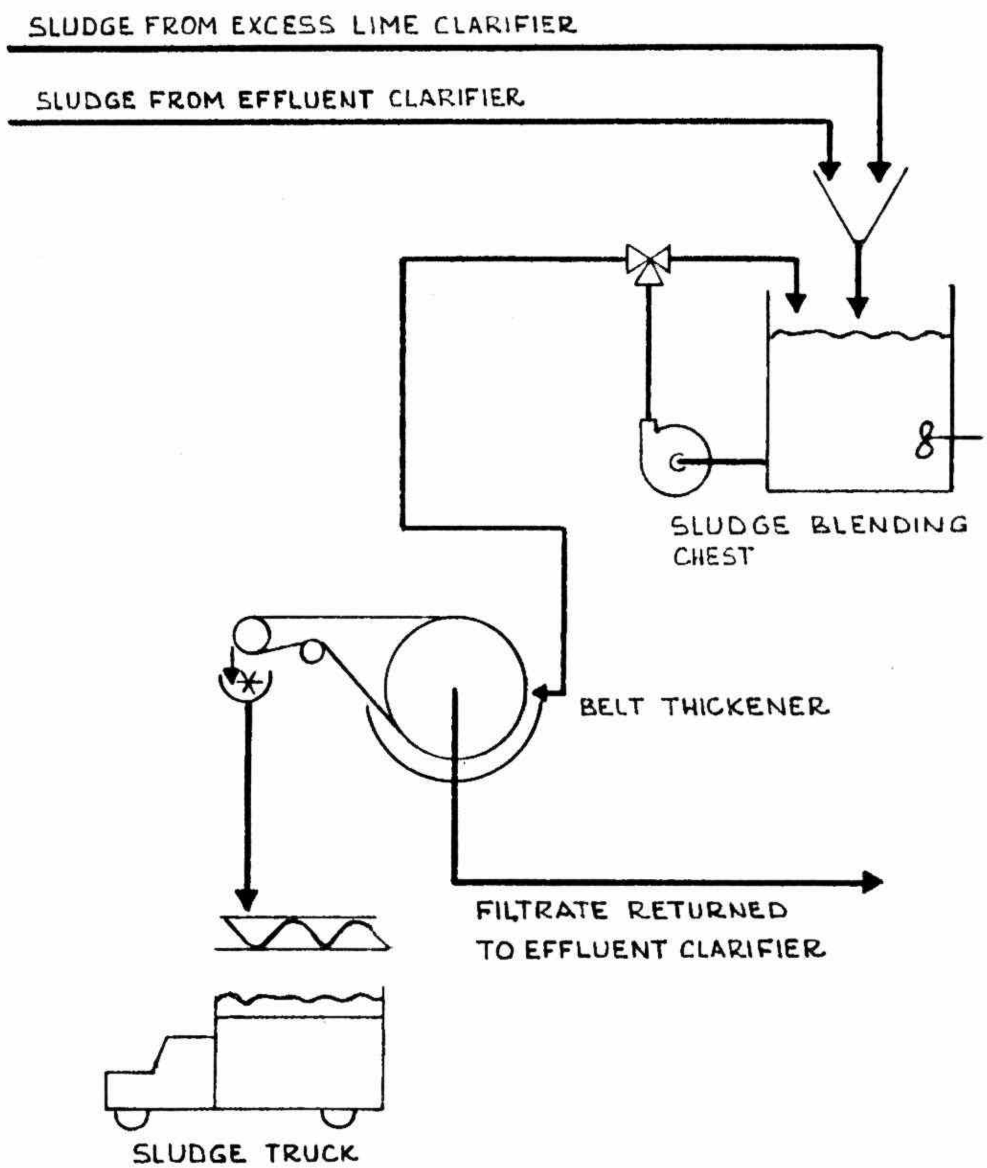
BLOCK DIAGRAM SHOWING WATER FLOWS ~ FIG. N° 1



WATER PLANT PROCESS
FIG. N° 2



WATER BLEED TREATMENT
FIG. N° 3



SLUDGE HANDLING SYSTEM
FIG. N° 4

Figure 7: Temperature °F

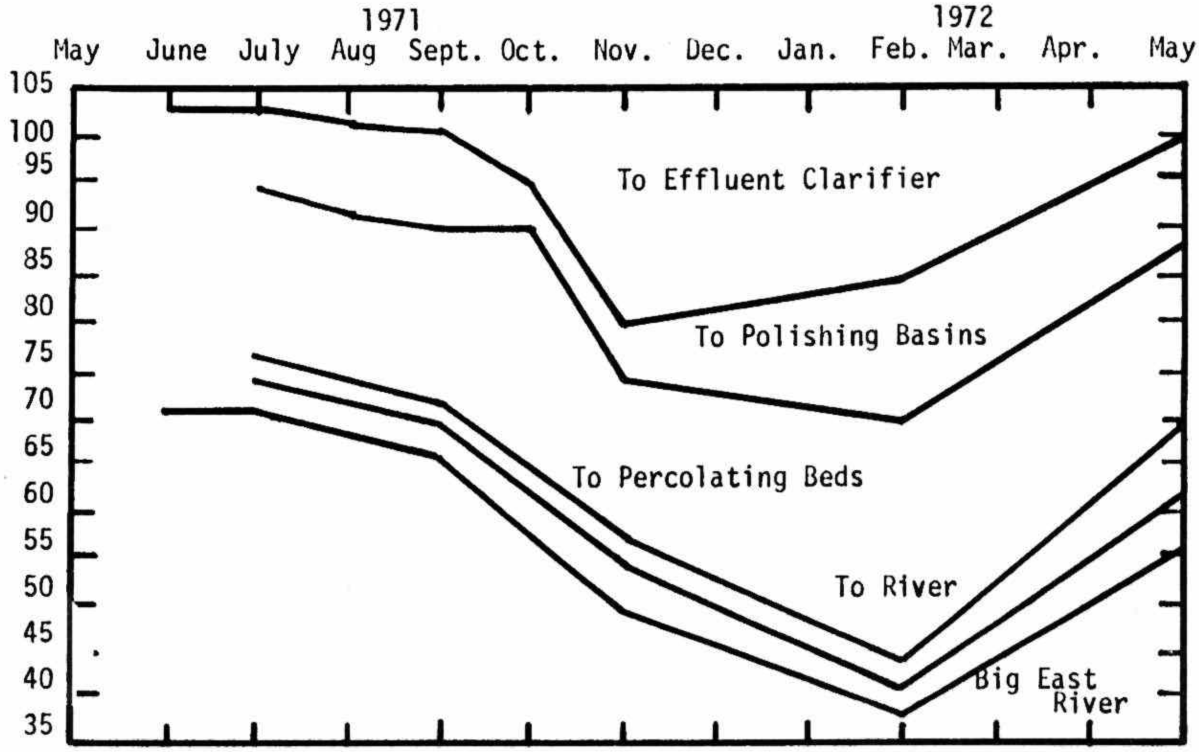


Figure 6: COD, ppm

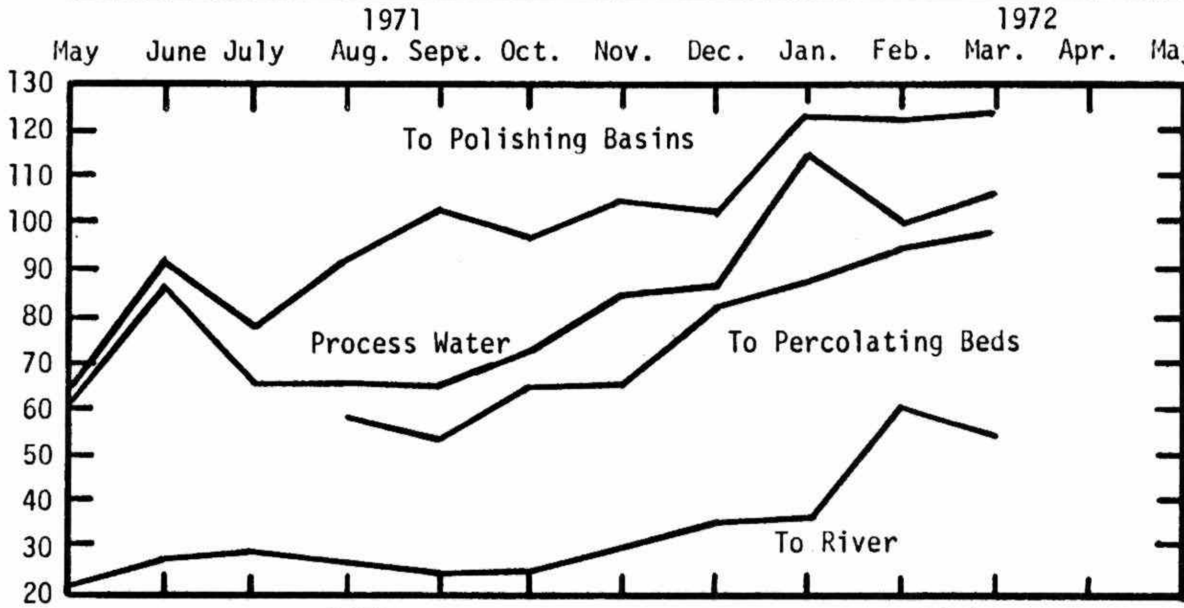


Figure 5: Suspended Solids (ppm)

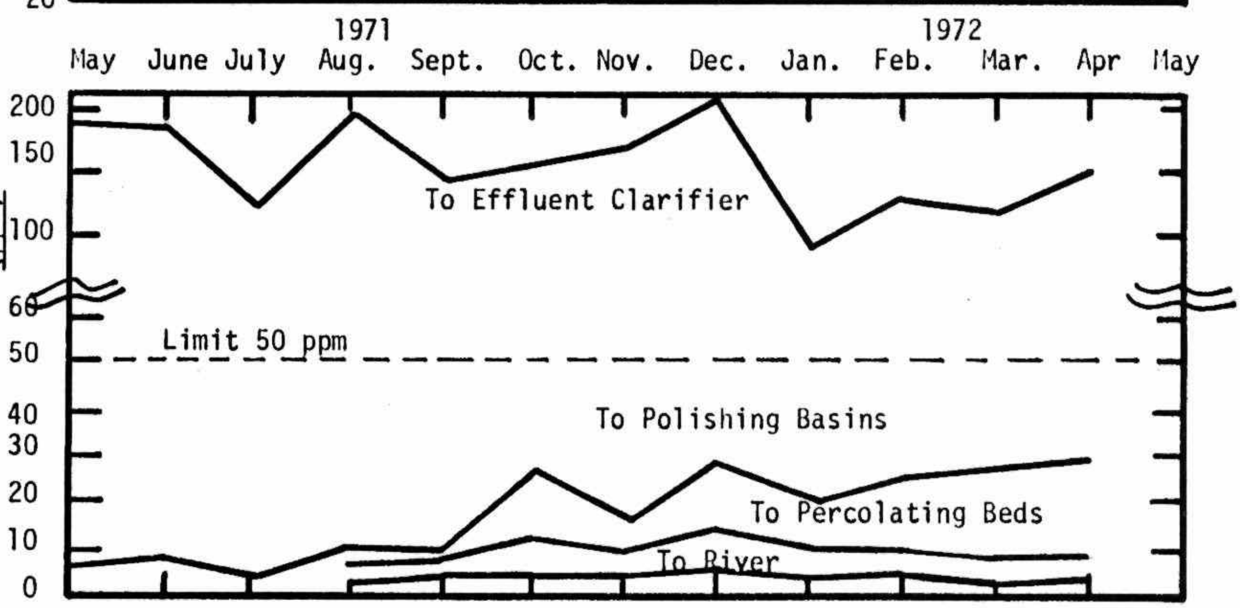
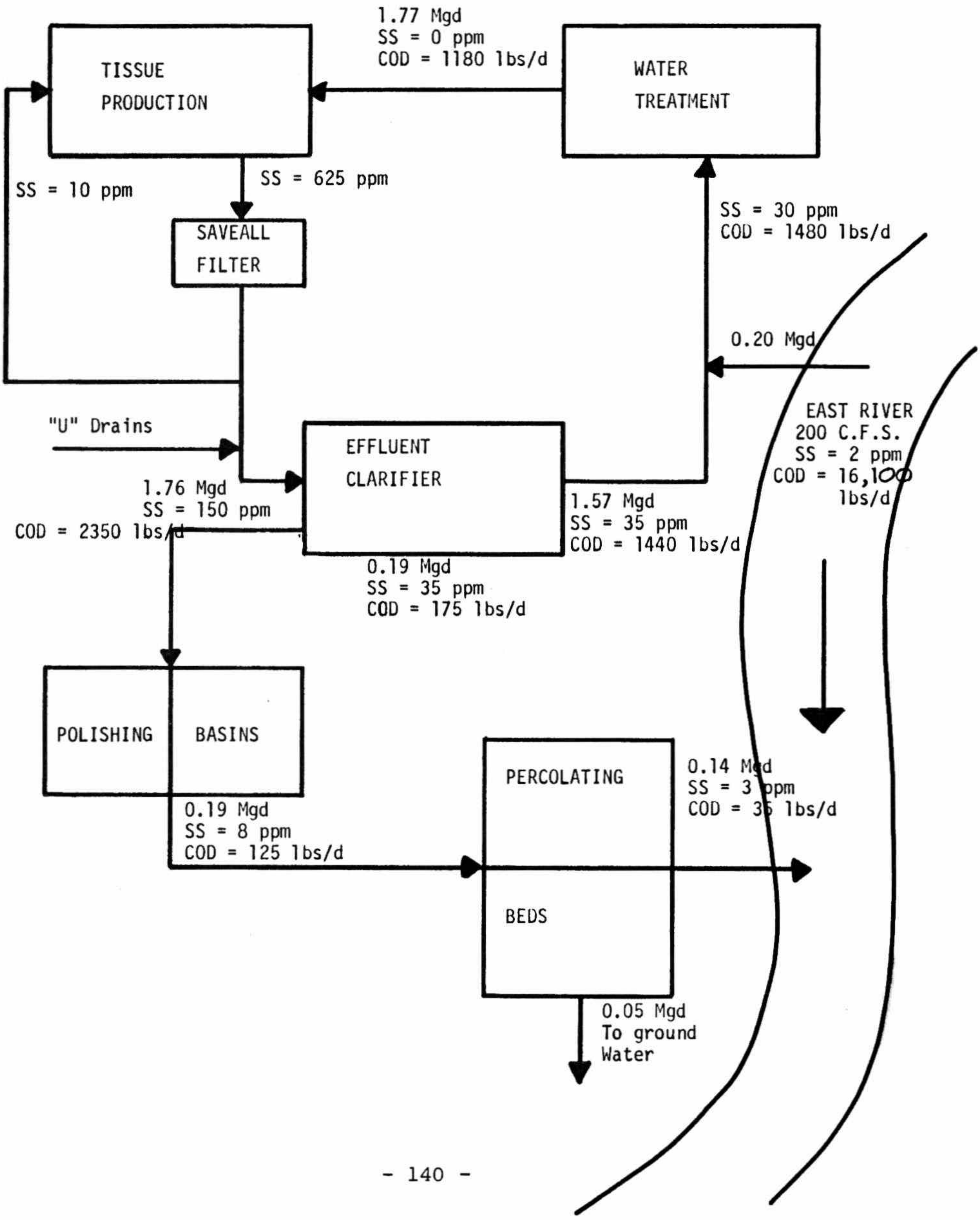


Figure #8: Typical Water Flows



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DEEP TANK AERATION USING A DIFFUSED AIR EDUCTOR TUBE SYSTEM

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Deep tank aeration systems, a development for deep reactor tanks, 20 ft to 35 ft W.D., possess unusually great merit, based on both large scale research and practical plant operation experience. We introduced this to Detroit (work done in their experimental test tank 24 ft W.D. x 70 ft wide, during 1967 thru 1969) and the findings were: excellent stirring; well distributed turbulence and excellent DO uptake (deoxygenated water technique). George Hubbell, in a paper on "Design Considerations - Detroit", 17th Annual Wastes Engr. Conf., U. of Minn., January 8, 1971, stated that the deep reactor test unit uptake rate (tap water) consistently ran between 12% and 14%. Our experience now establishes that the performance in industrial wastes is even more outstanding, yielding equal uptake rates and better process response than could have been anticipated from tap water studies.

A discussion of the background of this development is in order:

ROLLING AERATION - (Round subsurface Eductor Tube in a Deep Aeration Tank)

We first applied this in applications primarily involving aerobic digestion. In our testing, we diffused the air variously, about 8 ft. or 12 ft. below the liquid surface in large diameter subsurface eductor tubes. These eductor tubes operated in the center of large, deep tanks (often converted digesters) extending from about 5 ft. above the floor to within 6 ft. of the surface.

In these eductor tubes with subsurface discharge, measured circulation performance was found to be enhanced by placement of a flat amplification baffle at the water level surface to prevent geysering. This surface baffle acts at the surface to turn and amplify the radial stirring velocity of the air lifted flow; and increases pumping capacity by 10% or more, depending on the air loading parameter - air diffused per sq. ft. of eductor tube.

Testing disclosed that stirring and oxygen uptake for any given depth of air diffusion varied with both the criterion-cfm of air per square foot of eductor, and the uniform coplanar distribution of air release. As regards coplanar air release, unless skillfully designed, the actual airlift effect may actually commence at a point well above the plane of the air release, thereby lessening the real submergence ratio, which in turn dictates pumping ability.

Also disclosed was that, with any large eductor tube airlift system, the horizontal egress of water particles is more efficient near the projection of the eductor wall than farther back, i.e., particles near the center of the air lifted mass have more difficulty egressing into the stream; so that the greater the eductor tube diameter, the less the pumping efficiency. Tubes 10 ft. in diameter are not as efficient as tubes 4 ft. in diameter.

By stopping the top of the eductor tube a couple of feet above the plane of diffusion, where the airlift action is established, some boundary layer drag can be reduced, and favorable slipstream interface drag above the top rim of the eductor can be enhanced.

A limitation of the round eductor tube unit, besides overly large diameter, is that it can only be used in a radial vector circulation pattern, and cannot be used in a SwirlMix attitude. Besides that, a radial vector system is not as effective to stir large diameter vessels as is an elongate eductor system with vectors streaming at the surface normal to the long axis of the eductor tube.

DEEP TANK AERATION - (Rectangular Subsurface Eductor Tube System in a Deep Tank.)

This system is a new invention and corrects some of the inherent disadvantages of the large round eductor tube which could not be arranged in a SwirlMix regime. It also takes advantage of deeper stirring - greater intensity of air energy-to-surface release, which not only increases important surface aeration turbulence, but also which re-entrains fine bubbles for deep subsurface oxygenation.

This new system uses eductor tubes (narrow, rectangular in plan) to cause over-all circulation all the way from the bottom of the deep aeration reactor. The air is diffused only about 12 ft. below the surface in this eductor tube system, thereby profiting by many advantages because of the low air compression pressure. These long relatively narrow (about 5 ft. wide) eductor tubes correct the otherwise less efficient pumping that would take place if the tubes were round and, of necessity, very large in diameter (say greater than 10 or 12 ft).

These eductor tubes use the all-important amplification baffle, designed in the form of a shallow V at the surface. The amplification baffle streams vectors near the surface, normal to the long axis of the eductor tube.

The amount of energy used in a reactor for synthesis reactions tends to become greater as the art advances, and MLSS and substrate space loadings increase. Accordingly, deeper (22' - 35' W. D.) reactors involve too much air release to be efficiently handled in round eductor tubes. Now, the application of the long rectangular eductor tube does make practicable the application of shallow (12 ft submergence) air diffusion to deep aeration tanks.

With this rectangular eductor tube, not only is the narrow width and the cfm (air)/sq ft (eductor) designed to ideal parameters but also the surface vectors are discharged both ways, normal to the long axis; rather than from a point radially. Because of this, the more efficient SwirlMix stirring and oxygenating regime can be used to avoid "dead" cores and enhance DO uptake.

AIR DIFFUSION - (Manner and Depth of)

The air is diffused in a plane near the upper part of the eductor tube, through a diffuser grid system located about 12 ft

below the liquid surface. This system uses 5 1/2 psig air pressure including submergence and orifice system loss.

One of the important advantages of the deep aeration system, is that the air needs only to be compressed to about 6 psig. Thereby, standard, medium pressure centrifugal blowers can be employed, less heat of compression is dissipated and less energy (BHP) is required per unit of DO. The efficiency of this system depends, among other things, on the submergence ratio which (assuming good coplanar diffusion) runs in the high 90's. We have experimented with lesser submergences too, but any great reduction in submergence when oxygenation is important, is not economical.

Air diffusers mounted on the floor of deep tanks would require additional (wasted) heat of compression power and would change the submergence ratio, causing circulation, only to a minuscule extent - effecting only little additional stirring and oxygenation.

Since it is only required that the homogenized mixture of air-and-liquid be just established (causing the imbalance energizing the sub-surface airlift) the confinement of the eductor much above the plane of air diffusion can be omitted. Accordingly, the eductor tube only extends from an entrance of 5 ft. above the tank bottom to 2 ft above the plane of air diffusion; saving some boundary layer drag and increasing the secondary drag current between the slipstream and the surrounding liquor above the tube.

The fineness of the air diffusion to initiate the airlift effect is not so important as the coplanar distribution. However, an unreasonable large spacing of large bubble release points will not be satisfactory because the discrepancy in elevation between where the air is discharged and where it actually forms a well distributed homogeneous mass may be so great as to reduce the airlift pumping (and consequently oxygenation) efficiency. Such a discrepancy might well lose three or more feet of real submergence, thereby adversely affecting the true submergence ratio. Carelessness in detail on this point well might sacrifice up to 20% of the circulation and oxygenation efficiency.

SWIRLMIX REGIME: *

To effect the SwirlMix regime, two or more rectangular eductor tubes are placed at about a 30° angle with the centerline between them. The length and number of rectangular eductor tubes are selected so that the opposing surface vector systems tend to pass each other as a couple; rather than to run into each other in opposition (vector cancelling).

* Trade name of Walker Process Division of CBI Co.

This sets up a complex system of swirling currents in addition to the over-all roll that yield better and more well distributed turbulence than any other system is capable of. Such a system can eliminate all "dead" core pockets so apt to be present in simple toroidal or helical roll regimes. One can expect an ordinary uptake rate response of between 12% and 14% in tap water; with test extremes running as high as 18%.

The SwirlMix oriented eductor tubes, can be placed in either deep, long rectangular tanks, or in deep round tanks. The round tanks make very efficient reactors when arranged for SwirlMix, and can be built of steel if above ground.

CIRCULATING CURRENTS

In a properly arranged deep aeration regime, the surface region vectors are so strongly turbulent (standing waves) as to maintain a rather violent surface-aeration effect. Also, voluminous quantities of fine air bubbles are carried down at all points of fold-in and down-draft circulation.

Small (± 1 1/2 mm) air bubbles are carried down by currents greater than one fps and, once started, will be carried down to the bottom. These entrained bubbles moving with the turbulent mass turn at the bottom and are carried back in a meaningful quantity toward the eductor suction. During horizontal transit, these air bubbles detrain and pass upwards to form secondary airlifts and oxygenation.

The drag current affected by the boundary layer adjacent to the fast rising air lifted column above the eductor lip carries induced flow. The net effect is another current splitting from the main current approaching the bottom mouth of the eductor and rising on both sides, and adding to the over-all stirring.

The aeration process effectiveness of this deep aeration system is far greater than a traditional spiral roll regime (which has real faults - c. f. Milwaukee Journal WPCF, July 1968, P. 1310). Its effectiveness is even greater than a 15 ft water depth open diffuser SwirlMix regime.

THE AMPLIFICATION BAFFLE (Energy recovery baffle)

The near-surface amplification baffle, in the form of a long, shallow V-plate, is employed to eliminate the otherwise geysering hydraulic jump above the eductor tube; and to turn this energy into amplified streaming currents. This baffle is slightly wider than

the plan of the eductor; and has submerged vertical end baffles to divert endwise egress, and strengthen the normal vector system.

The baffle is rigidly fixed at, or a few inches below, the tank average water level so as to always be not much higher than the lowest operating water level. The V-shape, besides having hydraulic advantages, acts as stiffening for this baffle, which takes a great deal of hydraulic thrust. Also the apex of the V-baffle being slightly below the average tank water level, the roughly 8% by volume of large air bubbles detraining from the rising mass coalesce against the sloping surfaces and are expedited out of the liquid so as not to interfere with the formation of strong horizontal vectors.

The amplification baffle is what makes the submerged eductor system as efficient as it is, and accordingly, its design and exact placement is of vital importance; and no eductor tube system will operate very efficiently without it.

The aeration tank water level need not be controlled accurately. However, for reasons of the Baffle and also when centrifugal blowers are used, the variation between maximum and minimum flows should be designed to within 9 inches. Short time variations of about 12 inches will not affect over-all efficiency too much.

DEEPAER EXPERIENCE

Stepan Chemical Industrial Waste Treatment Plant (near Joliet, Illinois)

Stepan Chemical, a large supplier for a filler as utilized in the detergent industry, produces a high soluble BOD waste. The waste treatment plant was designed on the basis of a biological treatment feasibility report by Betz Laboratories, pursuant to extensive field testing in a pilot plant.

The one million gallons daily flow of the waste contains approximately 8700 lbs. BOD_5. The incoming waste is discharged into a long detention period clarifier tank, complete with skimming and sludge collector mechanism. This tank is not fill-and-draw, but operates with a standing overflow and with little equalizing effect. The varying flow is discharged throughout the 24-hours to a steel complete mix activated sludge reactor vessel of 100 ft. dia. x 24 ft. side water depth. Two proprietary sub-surface eductor tube aeration units, each about 5 ft. wide x 30 ft. long, are utilized to handle the 10,500 cfm (maximum) of air diffused into the two eductor tubes through a Sparjer

system mounted about 12 feet below the liquid surface. Each of the two eductor tubes are placed in a SwirlMix* position with an amplification baffle at the surface. The amplification baffle converts rising vectors into horizontal vectors causing near-violent surface stirring. The maximum air diffusion energy rate is 56 cfm/1000 cu. ft. of reactor - or 1.7 BHP/1000 cu. ft. of reactor. The plant has operated somewhat downwards from this rate; to often as low as 35 cfm/1000 cu. ft. - a remarkably low energy rate, considering the uptake demand of the waste and bio-mass.

The effluent from the deep aeration reactor is discharged to two final clarifiers, each 46 ft. dia. and equipped with multiple suction collectors, returning the 1% activated sludge underflow back to the aeration tank. The effluent overflow is at 300 gal/sq. ft. /day. Waste sludge is continuously fed to two aerobic digesters.

Two aerobic digesters are each 30 ft. dia. x 16 ft. SWD and each are equipped with a center sub-surface eductor tube unit utilizing 380 cfm of air. Decanting swing pipes on each aerobic digester are employed for intermittent decantation of supernatant; which is transferred to the influent pump pit. The aerobically digested sludge is disposed of by land fill and runs up to 4%. The digesters are designed to receive 1360 lbs/day of waste sludge (dry basis); a space loading of 0.05 lb/cu. ft. /day.

All of the structures described are built above grade and are steel tanks with steel bottoms. The entire project was erected by CBI Co. as a "Turnkey" project.

This waste is deficient in certain nutrients and these are fed to the raw waste stream. Operation results with this difficult waste have proven to somewhat exceed the pilot study results, and the plant has handled all of the "shots" that frequently are loaded onto it (which the pilot plant did not have to contend with since it handled blended wastes from a pond). Removals are about as follows:

<u>Stepan Chemical Operating Results:</u>

Data from the first 6 months of operation: -

Flow	700 gpm
MLSS	3500 to 4500 mg/l (at 4000 mg/l = 47,000 lb. of activated sludge)

Aeration Reactor 100' dia. x 24' WD = 190,000 cu. ft.

* Trade name of Walker Process Division of CBI Co.

Stepan Chemical Operating Results: (Cont'd)

Air 10,500 cfm

Performance	Applied to Aeration	Sed Tank Effluent	Filtered Sample
BOD	1038	50	10
COD	1800	250	-
TOC	500	60	-
TSS	-	30	7
DO	0	1.0	-

Uptake Rate:

Note: Calculated from Betz pilot plant study demonstrating α to be 0.7 and β to be 0.9; and 1 mg/l DO as encountered.

Air Absorption:

In waste treating 8700 lbs BOD, with 1.0 lb O_2/lb BOD and diffusing 10 million cu. ft. of air:

%E of air dissolution = 6.5% in MLSS with 1.0 mg/l DO.

%E of air dissolution = 12% in tap water (correcting for α and β and 1.0 DO).

Atlantic Richfield Co. Waste Treatment Plant
(East Chicago, Indiana Refinery)

This refinery waste resulting from manufacturing a wide range of petroleum products is a warm reasonably low sulphide content effluent from an API separator. The waste is applied directly to the bio treatment plant without equalizing. The design parameters and operation are about as follows:

Space Loading: 7.5 lbs/day/1000 cu. ft. of reactor
Air Diffusion: (max) 20 cfm/1000 cu. ft. of reactor
Solids Loading: 0.1 lb/day/lb of MLSS

TABLE I *

DESIGN PARAMETERS

	INFLUENT	EFFLUENT
Volume	2000 - 3500 gpm (7.6 - 13.3 m^3/min)	3500 gpm max. (13.3 m^3/min)
BOD_5	3000-4000 lbs/day (1360-1820 Kg/day)	10 mg/l max
Oil	3000-750 lbs/day (136-340 Kg/day)	10 mg/l max
Suspended Solids	600-1200 lbs/day (272-545 Kg/day)	10 mg/l max
pH	7.5 - 9.5	

Operation to date* has demonstrated that the loads estimated from the pilot work were quite typical, and that the operating results have equalled or exceeded the pilot plant performance. The resiliency of the relatively low space loading, well mixed complete mix system has proven adequate to handle shots and dumps without major upsets and certainly without process collapse.

The long retention (19 hours) activated sludge deep aeration reactors are two (2) - 120 ft. dia. x 24 ft. water depth steel tanks. These reactors are each equipped with two (2) long rectangular sub-surface eductor tubes about 5 ft. wide x 30 ft. long. Each tube has a unique surface amplification baffle to convert rising mass velocity into horizontal vectors, and the sparjed air is diffused about 12 ft. below the liquid surface.

The eductor tubes are placed in the SwirlMix ** position at a 30° angle with the centerline between them. In this way, the entire contents of the tanks are well agitated without any dead cores possible.

* Taken from "Deep Tank Extended Aeration System at Atlantic Richfield Co." by W.L. Rose and R. E. Gorringe. Purdue Waste Conf., 1972.

** Trade name of Walker Process Division of CBI Co.

Air use runs from a maximum of 5600 cfm for each reactor (20 cfm/1000 cu. ft. energy level) to often as low as 4200 cfm (an amazingly low 15 cfm/1000 cu. ft.). The deep aeration reactor is very well stirred throughout the range of air use with no dead cores or pockets anywhere - and no sludge banks any place on the bottom. This is a remarkable tribute to the efficiency of this deep aeration system and the canted SwirlMix stirring regime.

There are two final clarifiers 80 ft. in dia. equipped with special diffusing inlets with "oversized" feed wells, and multiple suction collectors. The surface rate is about 500 gpd/sq. ft.

Sludge is stabilized in a 33,000 cu. ft. aerobic digester stirred by a central sub-surface airlift eductor, and continuously decanted in a 16 ft. dia. clarifier. Digested sludge is exported by tank truck to a remote land fill site.

Detroit, Michigan - Municipal WPC Plant
(Under Construction)

Although not in operation, the aeration part of the plant, now well under construction, merits more than passing notice because of the careful testing work done here. The aeration* consists of five (5) deep aeration reactors 132 ft. x 60 ft. x 30 ft. WD each equipped with four - about 5 ft. wide x 22 ft. long sub-surface eductor tubes having surface amplification baffles formed by the bottom of walkways. The air is diffused about 12 1/2 feet below the surface, inside the eductor tube.

This design is backed up by over two years of extensive pilot work done in a large test tank in the Detroit plant to prove the worth of the eductor type deep aeration system. This system was tested under a wide range of contemplated aeration rates, in a tank 70 ft. wide x 24 ft. W.D. (and 16 ft. "long") having a single 14 ft. long eductor tube running across the middle. The tube was equipped with a coarse air bubble diffuser grid mounted 12 ft. - 6 in. below the water level, had sides and ends running from 6 ft. above the bottom to 6 ft. below the surface, and had a surface amplification baffle.

* The Detroit plant is designed utilizing two aeration systems in separate halves of the plant - the one described here by diffused air; and one utilizing direct oxygen.

The results were completely astounding. Not only was the stirring outstanding, with very good, well distributed fine and medium scale turbulence, but the uptake rate in "standard" deoxygenated tap water ran consistently 12% to 14%, over a wide range of aeration intensities. They also considered diffusing air at the bottom of the 24 ft. deep test tank, but elected to use the eductor tube with shallow (12 ft. -6 in.) air diffusion.

SUMMARY:

The sub-surface rectangular eductor tube stirring means is now a proven oxygenation system that can be reliably used in the operation of a more efficient bio-mass aeration system - deep tank aeration. Arranged as a SwirlMix regime, the over-all stirring and oxygenation per unit of air energy is enhanced.

These deep aeration tanks not only save in site area but, if cleverly designed, can save on over-all construction costs. Also, steel, circular tanks with steel bottoms are ideally suited to this type of design and should come into their own. Steel tanks are best built above ground level; and can be accommodated either by pumping the waste or by partial excavation and dyking.

The deep aeration system makes possible the use of six pound air blower pressures. The system is extremely efficient in stirring and oxygen uptake - so efficient that it rivals the practical working efficiency of any other commercial aeration system.

CONVERSION FACTORS

English Unit	Multiplier	Metric Unit
cfm	0.028	cu m/min
cfs	1.7	cu m/min
cu ft	0.028	cu m
cu ft	28.32	l
ft	0.3048	m
gal	3.785	l
gpm	0.0631	l/sec
gpm/sq ft	40.7	l/min/sq m
hp	0.7457	kw
in.	2.54	cm
lb	0.454	kg
lb/1,000 cu ft	16.0	g/cu m
mgd	3,785	cu m/day
psi	0.0703	kg/sq cm
sq ft	0.0929	sq m

R. Van Soest

A. L. Van Luven

HIGH RATE COMPLETE TREATMENT

BY

A. L. VAN LUVEN

and

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INTRODUCTION

The treatment of domestic and industrial waste has become one of the most urgent problems of our time. Not only are these problems increasing, but the cost of correcting them is becoming more and more difficult to bear. More than ever before, the challenge to our field has been to both cut costs and to improve efficiency.

Numerous innovations have been announced in the areas of biological, chemical, physical-chemical, and bio-chemical processes (1), (6), (7), (27). Although the cost picture for granular and powdered carbon systems is improving, biological systems have continued to be the most economical solution in most circumstances. These systems certainly do not deserve a quick dismissal, however, and are able to provide good treatment especially in the removal of colour and some refractory compounds which ordinarily pass through biological systems (6).

An approach taken in Europe and to a much lesser extent in North America has been the high-rate activated sludge process. To date, it is our feeling that certain modifications of this process offer not only low operational and capital costs, but also can produce effluent quality capable of meeting requirements of regulatory bodies. With reduced land requirements and construction costs through reduction in tankage requirements, the high-rate system can compete economically with most every alternative means of treatment, perhaps with the exception of lagoons.

High-rate activated sludge (HRAS) processes have been characterized sometimes very loosely in the past and for the purposes of this paper will be referred to solely on the basis of aeration tank loading rates greater than the conventional range of 25 to 50 lb BOD/D/1000 cu ft and the ability to provide intermediate to complete treatment (i.e. in terms of BOD removal).

The HRAS process is certainly not a new concept and has been studied for many years. In 1952, Garret and Sawyer (12) illustrated the rather surprisingly high potential of the activated sludge process. For a continuous, lab scale system with no sludge recirculation, they obtained the following data:

Temperature °C	Max. Specific Growth Rate (hrs)	Minimum Sludge Age (hrs)	Max. Removals $\frac{\#BOD_5}{\#MLSS\text{-}D}$
10	0.08	12.5	3.6
20	0.20	5	11.6
30	0.30	3.3	20.8

It should be noted that a loading of 20.8 $\#BOD_5$/#MLSS/D corresponds to a volumetric loading of over 2500 #BOD/1000 CF/D when the MLSS level is at 2000 mg/l and over 5000 #BOD/1000 CF/D at a MLSS of 4000 mg/l. These loadings are roughly 100 times the loading rates used in conventional activated sludge treatment.

In Germany, Kehr and Von der Emde (15), in pilot plant work treating municipal sewage found BOD reductions of 70-85% with loading rates from 100 - 900 lb BOD/D/1000 cu ft (and food to

mass ratios of 0.5 to 2.5 lb BOD applied/lb sludge solids).

Also in Europe, Pasveer (20) and Wuhrman (26) have confirmed the potential of high-rate systems through maintenance of high MLSS concentrations. This, of course, is contrary to the belief of some, that with high-rate activated sludge there must also be a low mixed liquor solids concentration.

As with conventional activated sludge systems, the HRAS process must provide an environment for biological growth and consumption of organic materials. In addition, and equally important is the second aspect of developing flocculant suspensions that readily settle and provide clarified effluents for final discharge to a receiving water course.

One of the greatest problems encountered with high-rate systems is the production of sludge particles which cannot be separated in secondary clarifiers.

It is the belief of some that the floc settling characteristics are determined primarily by the net specific growth rate (i.e. inverse of the sludge age) and the nutritional environment of the flora (4), (17). Mathematically, the sludge age can be expressed, (17) for completely mixed or plug flow systems as:

$$\frac{1}{\theta} = \frac{Q}{V} \left(1 + r - r \frac{Xr}{x}\right) \qquad (1)$$

where θ = sludge age - days

Q = flowrate - mgd

V = volume - million gallons

r = recycle ratio - R/Q

x = MLSS concentration - mg/l

Xr = sludge recycle concentration - mg/l

In general then, for high rate systems, the reduction in volume results in a reduction in sludge age and hence, a worsening in settling characteristics.

Relating zone settling velocities to organic loading, Ford and Eckenfelder (11) have found good settling for the following range of loadings:

Waste	lb BOD/D/lb MLSS
Brewery	0.2 to 0.6
Petrochemical	0.1 to 0.5
Domestic	0.1 to 0.8

The food to mass ratio or organic loading can be related to the sludge age by simple substitution into equation (1) of the expression:

$$F/M = \frac{So}{X}\,\frac{Q}{V} \qquad (2)$$

where F/M = food to mass ratio-lb BOD/D/ lb MLSS

So = input BOD concentration - mg/l

Therefore

$$\frac{1}{\theta} = \frac{X}{So}\,(F/M)\,\left(1 + r - r\,\frac{Xr}{X}\right) \qquad (3)$$

For a given waste, if X, So, r and Xr remain constant, increases in the organic loading will decrease the sludge age.

A preliminary consideration of high rate systems then indicates a feasible decrease in aeration tankage, but only at the expense of larger secondary clarification tankage and/or chemical addition. Unless the environment is then altered in some way to produce a settling floc (e.g. usage of oxygen and/or other means of selective acclimatization of cultures) settling properties alone can become a limitation.

Despite predictions of poor settleability, several high rate processes have been developed and reviewed. (5) (16) A Summary of some of the processes available include Step

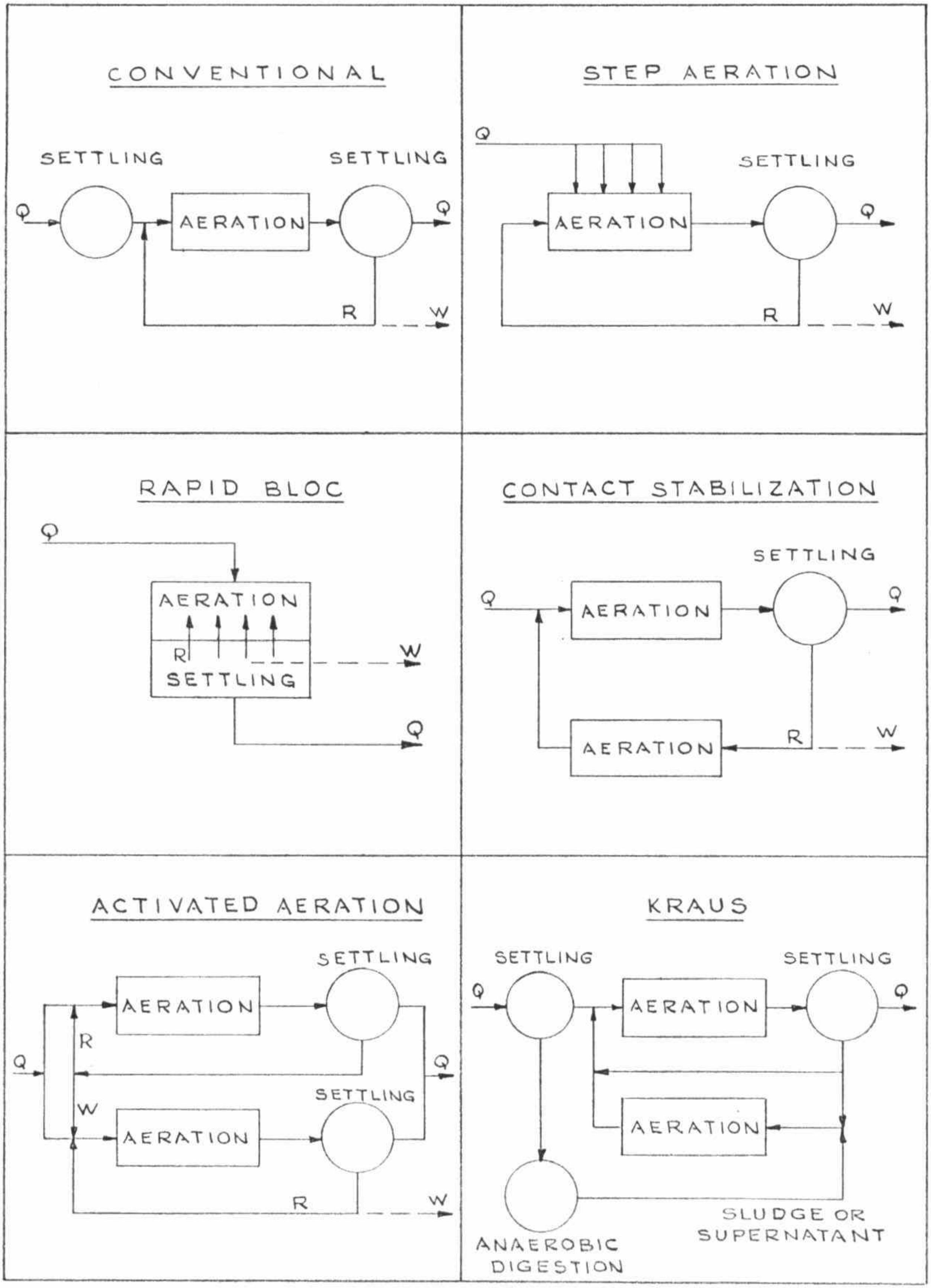


FIG. I PROCESS MODIFICATIONS

Aeration, Kraus Process, Biosorption, Contact Stabilization, Unox Process and the Zurn-Attisholz Process. Combined high-rate trickling filter and activated sludge has also been considered. (10) (13) Each is capable of providing BOD removals in excess of 85%. Others, providing slightly less efficient treatment include Activated Aeration, Modified Aeration and Supra-Activation. Table 1 is presented to illustrate typical operating conditions and expected operating efficiencies. The treatment processes are illustrated schematically in Figure 1. It is worthy of note that most of the processes have maintained food to mass ratios relatively low through higher mixed liquor concentrations. Variation is not significantly different from the good settling ranges found by Ford and Eckenfelder (11).

Combined tank systems such as the Oxycontact unit of Degremont or the Aero-Accelator of Infilco make use of the Rapid Bloc principle. Very high recirculation rates of 400 - 600% of plant flow are employed. Sludge thickening is not of major concern, and clarification is obtained by the provision of adequate surface area to enable an up-flow rate that does not exceed the settling or subsidence rate. With high recirculation rates, settling is aided by the bulk downward transport due to the sludge withdrawal from the settling zone.

Union Carbide (Unox) have claimed (30) that with the Unox direct oxygenation process, high D.O. levels and the low shear of solids (through low power levels) produce superior activated sludge settling characteristics. This is possibly because of the presence of higher order life forms of microorganisms (i.e. protozoa, rotifers, stalked ciliates, etc.)

The Zurn-Attisholz Process makes use of an interesting application of the two stage activated sludge process. Two high-rate stages are employed, the first utilizing a mixed culture predominant in bacteria and lower fungi, and the second stage, a culture predominant in protozoan microorganisms. Although the first stage bacteria may form dispersed growths that cannot be easily settled from water, solids carried over from the first

TABLE I

PAST DESIGN PRACTICE

OF

HIGH - RATE PROCESSES

Activated Sludge Process Modification	Degree of Treatment (% BOD Removal)	Primary Req'd	BOD Design Load: lbs BOD/Day / 1000 cu ft Aeration Tank	BOD Design Load: lbs BOD/Day / lbs MLSS	Cu ft air/lb BOD Removal
Conventional	95 +	Yes	35	0.33	700 - 1000
Step Aeration	92 +	Yes	50-150	0.33	500 - 700
Rapid Bloc	90 +	Optional	125-180	0.66-0.97	500
Unox	90 +	-	150-200	0.62-1.23	-
Zurn-Attisholz					
Stage I	90 + (overall)	Optional	250-600*	0.2 -0.7	600 (overall)
Stage II			20-180	0.5 -3.3	
Kraus	89	Yes	100	0.5 -0.7	800
Biosorption					
(Contact Stabilization)	85 - 90	Optional	70	0.25-0.50	750
Activated Aeration	80 - 85	Yes	50 +	0.33 Step Aeration Section	0.36 cu ft per gal
Modified Aeration	60 - 75	No	100	3.3-5.0	400 - 600
Supra Activation	55 - 65	No	400	3.3 -5.0	350 - 400

*Some mills are being operated at loading rates in the range 600 to 1000 lbs/day/1000 cu ft with excellent results. Design rates of 800 lbs/day/1000 cu ft will be used for certain mills because pilot plant work shows that this can be done.

References: (16,25,30)

stage clarifier are readily consumed as food by the protozoa. The protozoa, in turn, are about 100 times larger than bacteria and can be readily settled from the water in a second stage clarifier.

With the definite application of multiple stage systems for removal of colour, phosphorus and nitrogen (2),(9),(19),(22),(28) and the stability of the system relative to other activated sludge systems, Van Luven Consultants have taken considerable interest in this process.

It is our intention to introduce this process to you this afternoon, presenting some of the basic principles of operation, control methods, and some operational and capital cost figures. This process is not well known in North America although 22 plants are in operation throughout Europe treating domestic, industrial and combined effluents. (34 additional installations are under construction at this time.) Despite the requirements of two clarification stages, very high aeration tank loadings have enabled low capital costs as well as effluent BOD and suspended solids concentrations of less than 25 ppm.

II ZURN-ATTISHOLZ PROCESS - BASIC CONCEPTS

Separation of Cultures

The removal of organic impurities from sewage and industrial wastes is dependent on the presence of bacteria, lower fungi and also protozoa. In conventional processes, the organisms must function in the same environment. The vital requirements of the two groups of organisms (i.e. bacteria and protozoa) however are quite different. (9) Aerobic bacteria have been shown to be much more resistant than protozoa to environmental changes such as the introduction of toxic substances or depressed levels of dissolved oxygen. The speed of reproduction of bacterial cells and, consequently, their capacity for waste treatment is very great.

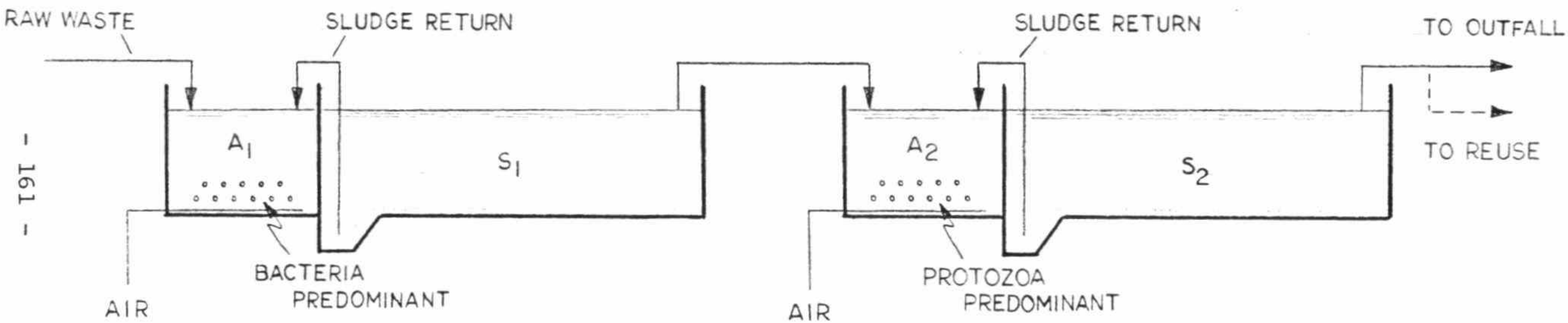


FIG. 2 - ZURN-ATTISHOLZ PROCESS

Protozoa require higher D.O. levels to develop. In general, they are more delicate than bacteria and consequently, more susceptible to toxic substances. Their speed of reproduction is considerably slower and therefore, their waste capacity is more limited. However, the role of protozoa in clarifying activated sludge effluents (i.e. as scavengers which remove bacteria from solution) has been recognized by several workers (3),(8),(14),(18).

The Zurn-Attisholz process takes advantage of the separation of each species in a two stage process to improve the quality of effluent in terms of both BOD and S.S.

As shown in Figure 2, a bacteria predominant culture is aerated with the raw waste in A_1 and settled in S_1. The "clarified" effluent of S_1 containing some bacteria carry-over is aerated in A_2. The total oxygen demand is low in A_2 but the concentration of residual D.O. is kept high to maintain a predominance of protozoa. The protozoa are settled out in S_2 and the clarified effluent is usually discharged, or in the case of industrial applications, the effluent is recycled to the process whenever possible. Recirculation of clarifier underflow is independent in each stage.

Mixed Liquor Suspended Solids Concentration

Making use of a second principal, of high bacterial concentrations in Stage 1, the Zurn-Attisholz process has been able to substantiate effluent quality predictions made by both Wuhrman (26) and Pasveer (20) with 90%+ BOD and suspended solids removals. Dubach (9) has found, however, that single stage mixed cultures have great difficulty functioning at high mixed liquor volatile solids concentrations (i.e. 7000 - 12,000 mg/l). He has attributed this to rises in oxygen consumption due to endogenous respiration of the sludge. Even if the oxygen supply is sufficient to maintain the growth of protozoa in the aeration tank, it becomes depleted shortly after entering the settling tank. This oxygen deficiency will check the growth of protozoa or stop it

altogether. The bacteria content of the effluent then rises and the purification effect deteriorates.

With the feasibility of maintaining high bacterial mixed liquor concentrations, the improvement in operation predicted by Pasveer (20) and Wuhrman (26) have become evident through increased carbon elimination, and in better elimination of organic matter at low temperatures. In addition, Dubach claims greater resistance to toxic components. This, of course, is all without the problems of high bacterial solids carry-over from the second stage.

Generally, mixed liquor concentrations in the second aeration tank have produced acceptable results when in the range of 500 to 1000 ppm. (For system flexibility reasons, the second stage aeration tank is often the same size as the first stage tank.)

Biological Reaction

The low oxygen requirement of the process as shown in Table 1 is attributed to a fermentation elimination process by Dubach (9). In conventional systems, where there is an abundance of oxygen, sugar will be eliminated by a series of complex reactions which can be written in an approximate overall form as:

$$\underset{100\text{ gms}}{\text{sugar}} + \underset{30\text{ gms}}{O_2} \xrightarrow{\text{M.O.}} \underset{50\text{ gms}}{\text{M.O.}} + CO_2 + H_2O$$

However, under the oxygen deficient conditions in Stage 1 aeration, the following reaction is said to occur:

$$\underset{100\text{ gms}}{\text{sugar}} \xrightarrow{\text{M.O.}} \underset{50\text{ gms}}{\text{alcohol}} + CO_2 + H_2O$$

$$\underset{50\text{ gms}}{\text{alcohol}} + \underset{15\text{ gms}}{O_2} \xrightarrow{\text{M.O.}} \underset{25\text{ gms}}{\text{M.O.}} + CO_2 + H_2O$$

Hence, theoretically, a total elimination of sugar can be effected with half the oxygen and, by comparison, produce only one half the microorganisms. The overall equation being:

$$\underset{100\text{ gms}}{\text{sugar}} + \underset{15\text{ gms}}{O_2} \xrightarrow{\text{M.O.}} \underset{25\text{ gms}}{\text{M.O.}} + CO_2 + H_2O$$

(M.O. = microorganisms)

Low wastage requirements have been substantiated in full scale operation. Dubach claims solids production figures of 0.5 lb S.S. per pound of BOD removed. In addition, the low wastage has permitted the sludge age to be maintained in the range of 3.5 to 20 days.

Energy Requirements

Neglecting for a moment the above theoretical consideration, it is well known that the aeration power consumption is inversely proportional to the oxygen deficit. Or in other words, as the residual D.O. in the aeration tank decreases, the driving force for oxygen transfer increases, and less energy needs to be supplied. The Attisholz process operates under oxygen deficient conditions in the first stage. Nearly all the oxygen that is transferred to the waste is consumed and very little excess is provided to increase this residual D.O. The first stage operates at D.O.'s usually less than 1.0 mg/l with BOD removals in the order of 80 - 85%.

Horsepower requirements can be expected in the order of 0.40 - 0.45 hp-hr/lb BOD_r (0.66 - 0.74 kw hr/kg BOD_r).

Biological-Chemical Treatment

In recent years, the applicability of staged biological systems for removal of nitrogenous and phosphorous materials

in addition to carbonaceous materials has been well illustrated. In the particular area of nitrogen and phosphorus removal, Barth et al (2) have closely parallelled the studies of Dubach in Europe. They have developed a three-stage modular process of high-rate activated sludge, nitrification and denitrification. In addition, phosphorus is chemically precipitated in Stage 1 with sodium aluminate and removed with the waste activated sludge. (Stage 1 employs a reduced aeration period only.)

The inability of conventional activated sludge plants to fully oxidize all of the ammonia has been attributed to the slow generation times of the nitrifying organisms. In the presence of the heterotropic organisms that utilize carbonaceous material, the longer generation time of the nitrifiers results in their wash-out during wastage of the excess heterotropic sludge.

The work of both Dubach (9) and Barth et al (2) have indicated that the aeration time required for nitrification can be reduced by separating the major portion of the carbon oxidation and cellular synthesis from nitrification.

In the Zurn-Attisholz process, the second stage MLSS content is increased from the range 500 - 1000 mg/l to 2000 - 3000 mg/l in order to develop the nitrifying bacteria. As with the process of Barth et al, (and later work by Mulbarger (19)) the high-rate effluent containing some residual carbonaceous material and most of the nitrogenous material in the form of ammonia, is oxidized in the second stage aeration tank. With a greatly reduced loading of carbonaceous material, cellular synthesis is low and consequently, no wash-out of nitrifiers occur.

As with protozoa, the high mixed liquor concentration in Stage 1 affords protection to the nitrifiers from toxic components.

TABLE II - CHANGE IN CONCENTRATION OF VARIOUS CONSTITUENTS DURING TREATMENT*

Constituent	Raw Wastewater (mg/l)	Primary Effluent (mg/l)	High Rate Effluent (mg/l)	Nitrified Effluent (mg/l)	Denitrified Effluent (mg/l)	Denitrified Effluent (filtered) (mg/l)
COD						
Average	320	218	64	43	44	38
Range	95-1,195	67-566	24-328	17-239	21-194	15-194
Organic-N						
Average	10.3	5.9	0.8	0.4	0.4	0.2
Range	2.3-31	1.4-12	0.8-1.4	0.0-1.0	0.0-1.7	0.0-1.6
Ammonia-N						
Average	11.3	13.7	7.7	0.6	0.3	0.4
Range	0.2-24	2.5-21	0.2-16	0.0-6.0	0.0.212	0.0-2.3
Nitrite-N						
Average	-	-	1.1	0.3	0.3	0.4
Range	-	-	0.0-5.8	0.0-2.6	0.0-1.8	0.0-1.9
Nitrate-N						
Average	-	-	4.3	11.5	0.9	0.9
Range	-	-	0.0-10.5	3.7-24.8	0.0-7.5	0.0-6.1
Total phosphorus						
Average	12.6	11.9	2.8	2.6	1.5	1.1
Range	3.0-30	3.0-26	0.4-11.3	0.7-8.2	0.2-5.3	0.2-4.5
SS						
Average	157	90	8.8	7.1	7.1	1.7
Range	40-800	28-236	0.0-39	0.0-54	0.0-45	0.0-7
pH						
Mode	7.2	7.3	7.5	7.5	7.7	7.7
Range	6.7-7.6	6.9-7.6	7.2-7.8	7.1-8.0	7.0-8.3	

*Each average is result of 40 determinations.

The third stage denitrification system employed by both Mulbarger (19) and Barth et al (2) includes a further anaerobic stage under the presence of methyl alcohol. Table II is an example of the pilot plant results obtained by Barth for this system.

Considerable success has been obtained by Dubach (9) in lowering the nitrates discharged from the second stage by simply recirculating them to the first aeration stage. In an organic-carbon-rich source under active metabolism and oxygen deficient conditions (i.e. D.O. $<$ 1 mg/l) denitrification occurs readily. This approach is limited only to the extent that the removal of nitrates is dependent upon the fraction of the second stage effluent recirculated.

Very fortunately, it has been found (2,9,19) that the chemical precipitation of phosphorus compounds can be combined with the high-rate activated sludge, nitrification-denitrification processes. Barth (2) and Mulbarger (19) (to a lesser extent) have found reasonably good removals of phosphorus with the addition of sodium aluminate in the high rate stage.

The Attisholz process has given successful results with either aluminum sulphate or ferric chloride in the second stage aeration tank. It is of note, that neither of these chemicals are incompatible with the growth rates of protozoa, or the nitrosomonas bacteria in the quantities used. Typical phosphorus removals that have been obtained with the Attisholz process are as follows:

	BOD mg/l	Total P mg/l
Raw sewage	60 - 75	2.5-3.5
Stage 1 Effluent	8 - 10	1.5-2.5
Stage 2 Effluent	3 -4	0.2-0.4

Ferric chloride treatment, although suitable for phosphorus removal, was found to cause discolouration of the effluent and as a result is no longer employed.

III OPERATING RESULTS

Table III is a summary of some of the operating conditions and results obtained from three Swiss municipal treatment plants. As indicated by the table, primary clarification is seldom attempted for domestic wastes or industrial except when suspended solids concentrations are in excess of 500 mg/l.

With nutrient deficient wastes, nutrients are added in approximately the ratio BOD:N:P = 100:3:0.5.

Two areas of major concern are process stability and toxicity of effluents. Since none of the Attisholz systems are known to receive significantly toxic wastes, further work is necessary in evaluation of operation with more toxic wastes such as Kraft Mill Effluents. No toxicity problems have been encountered, however, with the wastes of fine paper mills, dairy products, and rendering operations.

One of the major claims of the designer, however, is the stability of the process to upsets through flow changes and increases in BOD loading, etc. As a result, far less instrumentation, controls and operator attention is required than conventional systems. The high bacteria content of the first stage is said to provide a buffer to shock loadings and the second stage continues as a polishing stage.

TABLE III

TYPICAL SEWAGE TREATMENT PLANTS

ZURN-ATTISHOLZ PROCESS

	Riedholz	Trogen	Marstetten*
Flow - USMGD (design)	0.80	0.52	0.77
BOD - mg/l	87	115	335
Primary Clarification	none	none	none
Stage I			
Aeration time - hrs	0.60	0.96	1.87
Loading			
- lb BOD/D/lb MLSS	0.23-0.43	0.19-0.36	0.29-0.54
- lb BOD/D/1000 cu ft	219	180	268
Settling Tank Loading			
- USgpd/sq ft	743	-	506
BOD removal - %	80% +	80% +	80% +
Stage II			
Aeration time	0.60	0.96	1.87
Loading			
- lb BOD/D/lb MLSS	0.70-1.40	0.58-1.15	0.86-1.72
- lb BOD/D/1000 cu ft	44	36	54
Settling Tank Loading			
- USgpd/sq ft	743	-	506
Effluent BOD - mg/l	10	15	20
S.S. - mg/l	-	10	10
Overall BOD removal	95%+	90%+	90%+
Total Phosphorus removal	79-90%	81-98%	54-93%

*Includes wastes from rendering and fermentation industries (cider, etc.).

ECONOMIC CONSIDERATIONS

An economic evaluation of the Zurn Attisholz process must consider the following features of the process:

1) PROCESS RELIABILITY

This two stage activated sludge process is the only modus operandi by which activated sludge systems can be operated at very high loading rates without fear of process failure. Moreover, the Zurn Attisholz process provides removals of BOD always greater than 90% and frequently 95 to 98%.

This high degree of reliability is accomplished by the two stages consisting of a) a roughing stage and (b) a polishing stage plus the flexibility described below.

The roughing process (Stage I Aeration) employs bacteria and lower fungi at very high concentrations and at very low levels of DO. These organisms are highly tolerant to pollution, (including toxic substances, fluctuations of pH, flow, temperature, etc.)

The polishing process (Stage II Aeration) employs protozoa which feed on the bacteria and lower fungi that may escape from the first stage.

Thus process reliability is accomplished without duplicating the tanks, excessive controls etc. Refer to item 5 below re adaptability.

2) LOW OXYGEN CONSUMPTION

In this process, the use of oxygen is greatly reduced by:

a) low DO level for the high MLSS (8000 to 15000 ppm) in Stage I where 80 to 85% of the BOD is removed.

   The need for oxygen is restricted until Stage II at which point the MLSS are reduced to the range 500 to 1000 ppm (up to 2500 or so when denitrification is required).

b) Removal of BOD by using facultative bacteria in Stage I. By so doing, there is an intermediate alcohol stage which converts about half of the sludge to carbon dioxide and water.

3) LESS POWER CONSUMPTION

The Attisholz people claim that the power required for the Zurn Attisholz process is about 1/5 of that required for single stage, high rate activated sludge processes. Certainly the power required is very much less.

4) LESS SOLIDS TO HANDLE

Refer to item 2(b) above. Undoubtedly, this effects a considerable saving over conventional processes.

5) ADAPTABILITY OF THE PROCESS

a) Processing Features

The process readily permits removal of phosphates, colour and other contaminants by incorporating chemical treatment into the process.

Denitrification is accomplished by recycling the highly nitrified effluent in Stage II to the Stage I aeration tank to supply much of the oxygen required there.

b) Construction in Stages

The Zurn Attisholz system is readily adaptable to construction in stages whereby one may assess the possibility of employing loading rates of 2 to 4 times those that may be acceptable in the final analysis. Thus experimentation may be done at very low additional cost to the owner. Moreover, the Regulatory Agencies would be almost certain of obtaining high degrees of treatment in this two stage system at loadings that are completely beyond the capacity of other systems. It must be realized that the additional expansion, if actually required, would involve the owner in only a very small amount of duplicated costs (adjustments to weirs, etc.)

c) Repairs

If any one of the Zurn Attisholz aeration tanks is shut down for repairs, the system may be temporarily converted to a high rate single stage activated sludge process. If one of the settling tanks must be repaired, the flow can be rerouted.

These rerouting possibilities provide all of the protection (and more) that is often provided by duplication of tankage, storage of sludge and costly control systems for other processes.

6) NO PRIMARY REQUIRED FOR SOME WASTES

The Zurn Attisholz system does not require primary clarifiers whenever the suspended solids in the wastes are less than 500 ppm.

7) PLANTS ARE SMALLER

The total retention time for the Zurn Attisholz system is in the order of 7 to 10 hours versus 12 to 15 hours for conventional activated sludge systems.

Generally speaking, the economic advantage of the Zurn Attisholz system over all other systems, increases very significantly as the wastes increase in concentration of BOD.

8) LESS CONTROLS REQUIRED

Due to the high rates of returning sludge to each of the stages of aeration, it is relatively easy to maintain the desired levels of D.O. and MLSS in each stage without causing local pockets of anaerobic conditions, or too much air in the first stage and without causing a lack of uniformity in the second stage.

Thus, the only control required in the system is the level of sludge in each settling tank (when D.O. and MLSS have been adjusted).

Various properties of the influent and effluent are measured and recorded, but these items require little operator time.

9) MISCELLANEOUS CONSIDERATIONS

It should be noted that natural laws govern the presence of bacteria and lower fungi in the first stage of aeration since higher levels of D.O. are toxic to these organisms. Similarly, the protozoa in the second stage of aeration cannot exist actively when the D.O. is less than 3.0 ppm.

Each of the following items may be installed in any activated sludge system, but the configuration of the Zurn-Attisholz system more readily permits:

a) Use of rectangular tanks with common wall construction, and single base slab for any size of plant. See Figs. 3 & 4.

It is realized that steel, circular tanks are more economical for smaller plants, but frequently, concrete must be used in certain industries.

b) Compact layout that incorporates laboratory, dewatering, aeration equipment and processing tankage within relatively small overall areas. See Figs. 3 and 4.

c) Use of airlift pumps for recycling sludge thus using some of the pumping energy for aeration.

10) RECYCLING

For most paper companies and probably for many pulping processes, the Zurn-Attisholz system is a real "break-through" in providing effluent that can be safely recycled to the mill processes. We estimate that 90% recycle would be readily acceptable to the paper industry.

The capital cost of the Zurn-Attisholz system is in nearly all cases competitive or lower than other biological systems. Fig. 5 and 6 show the predicted capital cost for North American facilities based on the Attisholz design parameters, but Canadian construction and equipment cost.

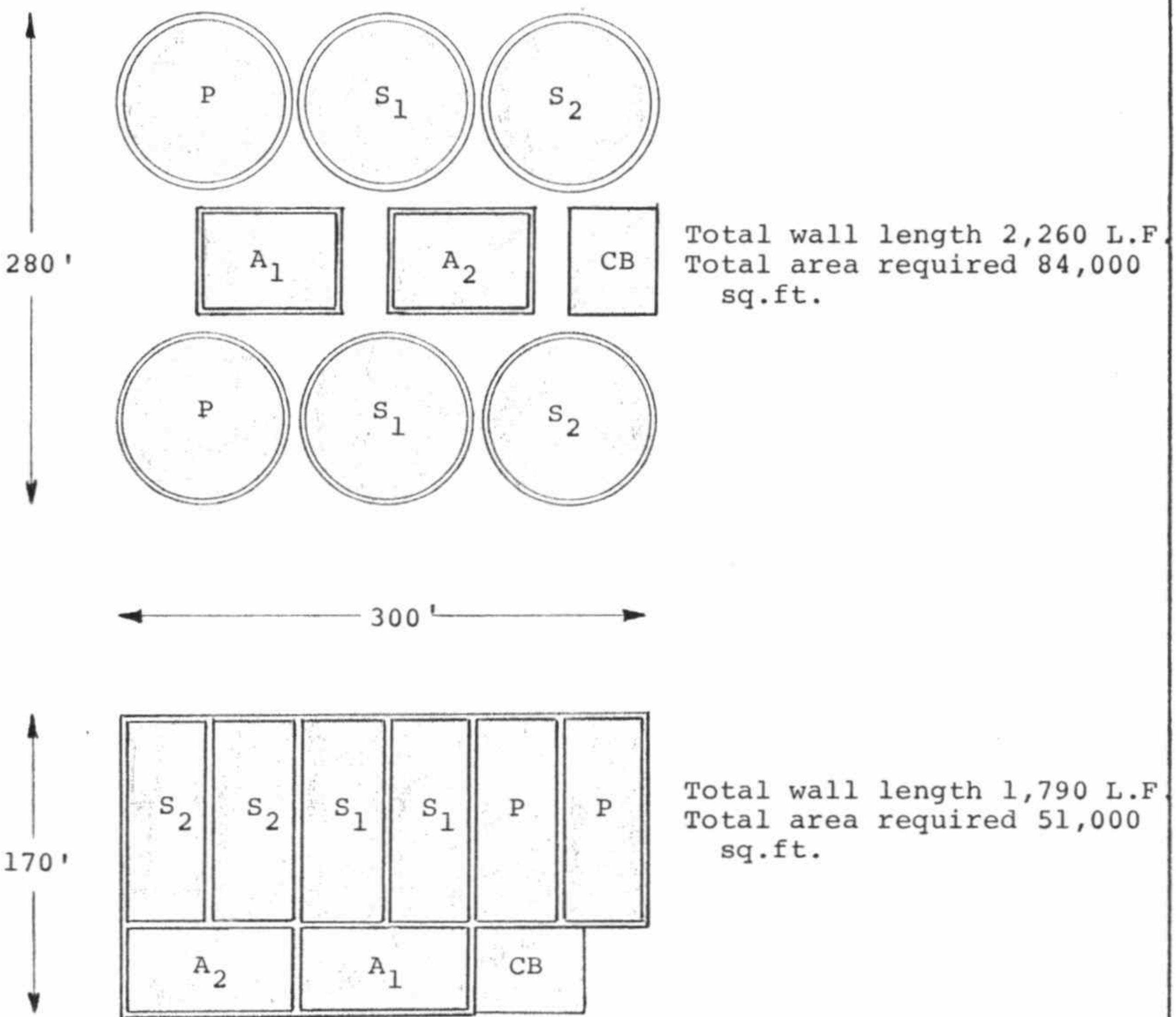
The capital cost includes:

- Primary Clarifier complete (which may not be required)
- Two-stage Zurn-Attisholz biological system complete
- Sludge Dewatering equipment
- Control Building with laboratory
- Instrumentation and auxiliaries
- Indirect cost, i.e. engineering, contingencies, contractor's fee, etc.

It does not include:

- Land
- Screening and grit removal
- Sewers and outfalls
- Pumping station

Fig. 5 also shows the cost(29) of conventional activated sludge, extended aeration, contact stabilization, aerated lagoons and high rate trickling filters. It is obvious that only the lagoons are cheaper. As mentioned before, many



Design basis
Flow 12 U.S.M.G.D.
BOD_5 180 ppm
S.S. 240 ppm

P = primary clarifier
S = secondary clarifier
A = aeration tank
1 = Stage 1
2 = Stage 2
CB = Control Building

Fig. 3 - Circular vs. Rectangular Tankage

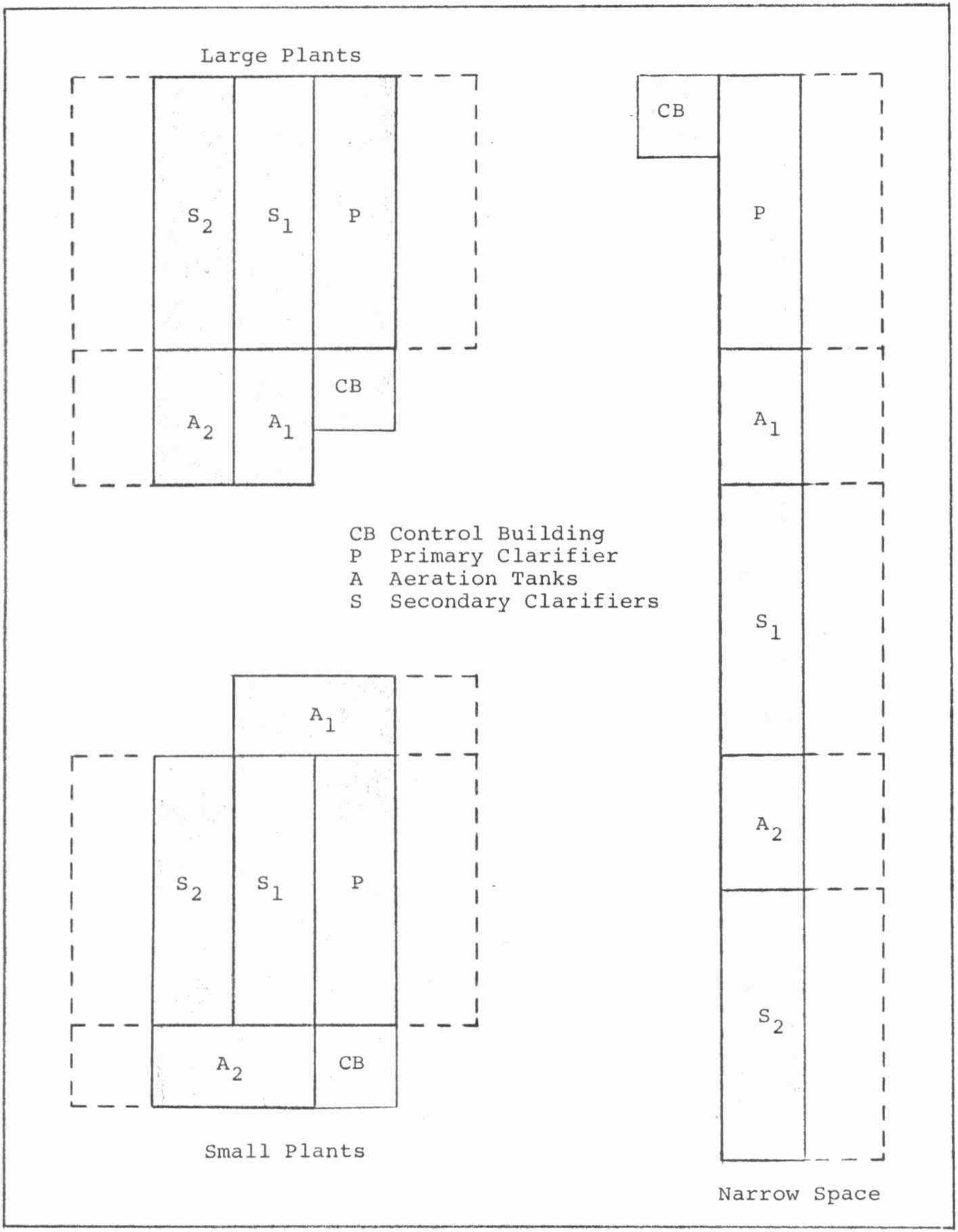


Fig. 4 - Three Preferred Layouts Showing Expansion Possibilities

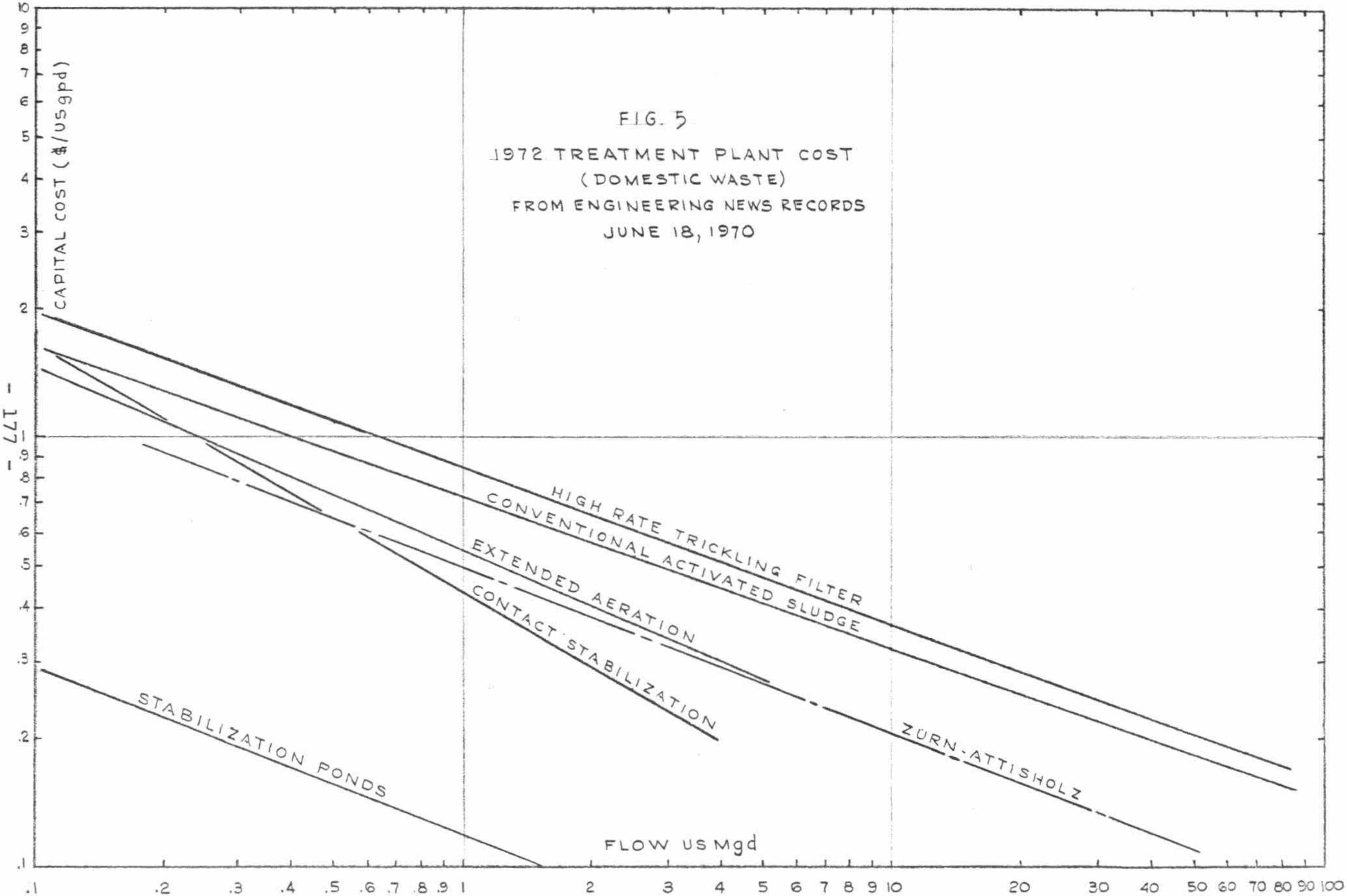


FIG. 5

1972 TREATMENT PLANT COST
(DOMESTIC WASTE)
FROM ENGINEERING NEWS RECORDS
JUNE 18, 1970

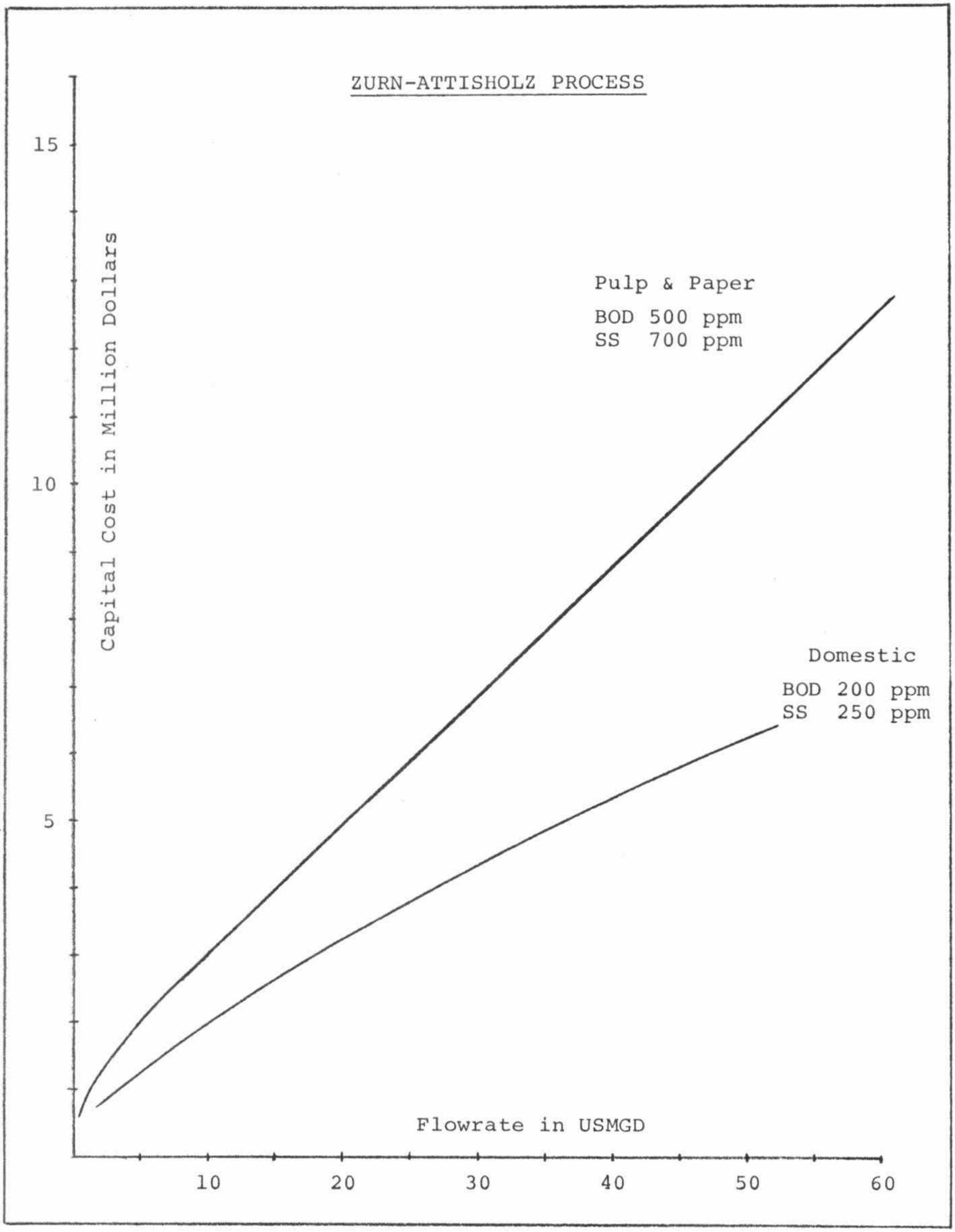


Fig. 6 - CAPITAL COST

Canadian companies have experienced difficulties with lagoons due to our cold climate. The curve for contact stabilization systems is suspect because of its distinctive difference in slope compared to the other processes. However, it is shown as represented in reference 29. We would expect this line to be more or less parallel to the others and roughly equal to the Zurn-Attisholz system cost. This feeling is shared by our colleagues in the consulting engineering field, with whom we have discussed this process.

The various Regulatory Agencies are having another look at these systems and may be forced to make some drastic recommendations as effluent restrictions become more severe.

Fig. 7 and Table IV show the expected operating cost for the Zurn-Attisholz system based on the inventor's claims. Fortunately, we were able to obtain operating cost for some of the OWRC activated sludge plants as well as those mentioned in Reference (31).

Most domestic Attisholz systems in Switzerland are inspected by one operator once a day. During a few hours he inspects the plant, takes samples, lubricates equipment, fills in the log book and cleans up. No full time staff is used. Even the large Fine Paper mill at Biberist (5 USMGD) is not continuously attended. Our labour unions may not accept this principle and may require several tradesmen to attend the plant. Larger industries that have all these trades on site anyway are in a better position. Here the water treatment plant operator could easily take care of the effluent plant as well. The operating cost shown on Fig. 7 has accounted for more operating/ maintenance staff than the European experience seems to require, but less than the staff as used by some of the domestic (OWRC type) plants.

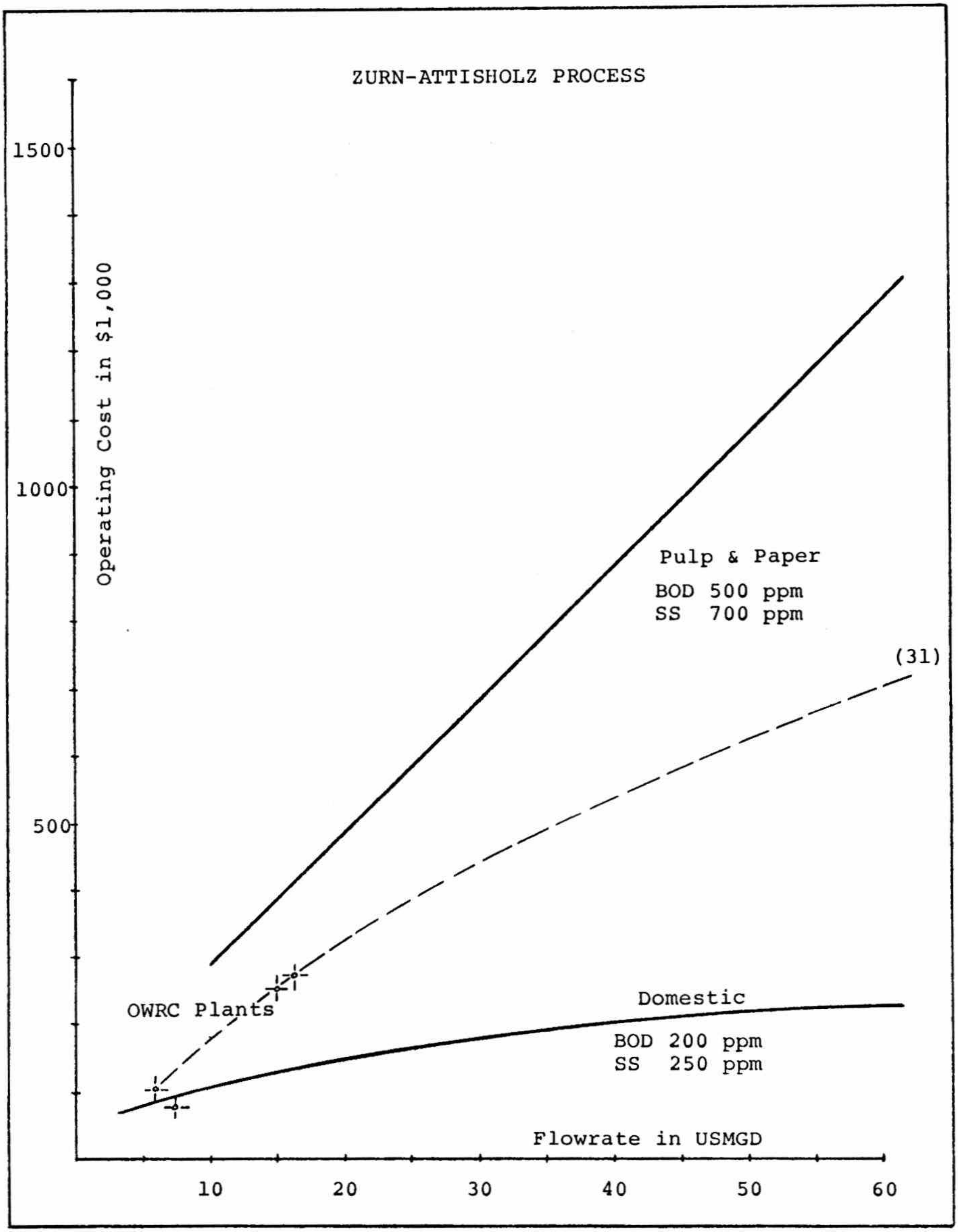


Fig. 7 - OPERATING COST

TABLE IV - ZURN-ATTISHOLZ PROCESS
OPERATING COST FOR DOMESTIC TREATMENT SYSTEMS

FLOWRATE USMGD	POWER	OPERATORS	MAINTENANCE	CHEMICALS	MISC.	TOTAL
0.1	500	15,000	2,000	500	3,000	21,000
0.5	500	25,000	4,000	1,000	3,000	33,500
1.0	1,000	35,000	7,000	1,000	4,000	48,000
3.0	2,000	50,000	10,000	2,000	5,000	69,000
5.0	3,500	50,000	13,000	3,000	6,000	75,500
10.0	6,500	70,000	18,000	6,000	7,000	107,500
30.0	19,500	100,000	30,000	18,000	9,000	176,000
45.0	29,500	100,000	38,000	27,000	11,000	205,500
60.0	39,000	100,000	45,000	36,000	13,000	233,000
80.0	52,000	100,000	60,000	48,000	15,000	275,000

NOTE: For industrial waste, often with higher BOD_5 and SS than domestic waste, the operating cost will normally be higher. Higher BOD_5 requires more aeration (power), while higher SS requires more dewatering capacity (power). Industrial wastes are often nutrient deficient and thus require chemicals.

IMPLEMENTATION

1) Domestic Wastes

The available data are sufficient for us to recommend this system for all municipalities. We would certainly want to analyse the site conditions in detail before providing estimates of costs, and deciding whether to proceed by package plant, or "tailor-made" design.

2) Combined Industrial & Municipal Wastes

There are data available for municipalities having such industries as - fermentation, packinghouse, rendering, chemical and other industries.

The proportions and properties of the industrial wastes would determine the need for pilot plant studies.

3) Industrial Wastes

Good data are available for paper mill, textile, packinghouse, pharmaceutical and various chemical wastes. However, for most industrial wastes, and all pulping wastes, Van Luven Consultants recommend the use of pilot plant studies. These studies should require about three months of continuous operating time.

4) Pilot Plant Studies

Pilot plant studies are presently being considered whereby we shall study North American conditions by using two pilot plants in parallel as follows:

a) Small scale bench-size unit with a maximum capacity of 6 litres per hour.

This unit will determine treatability and provide data to which the Attisholz factors for scale up can be applied.

b) 5 gpm unit with which we can assess the application of the Attisholz factors to North American conditions.

We are strongly convinced that lagoons only work in milder climates and even then, are not very attractive. Also, we feel that conventional biological treatment systems, and even the contact stabilization process have caused so many problems in operation and obtained such marginal results, that it has scared off most industries from using any biological system. But we are equally convinced that the high-rate system is economical, simple to operate and can consistently give a high degree of treatment if designed and operated on the Attisholz principles. Moreover, as stated earlier in this presentation, the Zurn-Attisholz system incorporates removal of nitrogen, phosphorus and colour.

There will always be limitations to any process or equipment, but we have not found these limits yet for the Zurn-Attisholz system.

From our experience with a single-stage high-rate activated sludge system, (pilot plant on fully bleached kraft mill effluents) we are convinced that activated sludge systems can be very successful at very high loading rates. We feel certain that the Zurn-Attisholz two-stage system will successfully avoid the currently unavoidable problems that result in low efficiency when certain unknown things happen in the mills. Moreover, we are convinced that this two-stage system, with its complete separation of the working forces, will do its work at very high removal efficiencies and at very high loading rates for most effluent problems.

The two-stage system also allows for stagewise construction. This may show that after the first stage is installed, no further treatment is needed for certain effluent problems.

However, we emphasize that the staging should be accomplished with a tank configuration that utilizes the Zurn-Attisholz principles at each stage, because as stated, the principle of dividing the bugs according to the function (and environment) for each, is the fundamental reason that permits successful operation of high rate activated sludge process.

At the first stage, the loadings could be extremely high (for example, double the predicted safe design loading required for 95 percent removal).

In addition to the foregoing, we now have some evidence that supports our contention that removal of toxicity from pulping effluents goes hand-in-hand with the removal of BOD. i.e. high removal of BOD produces relatively non-toxic effluents for the pulp and paper industry, at least.

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AUTOMATED ANALYSIS OF WASTEWATER QUALITY

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INTRODUCTION

The implementation of water quality management in the United States is moving toward a practical basis. Elements of this basis are effluent monitoring to meet legal requirements and the statement of those requirements in reliability terms. Quality control established on this basis places the burden with certainty at the source of problems. Insistence upon reliability of quality control is necessary. Reliability must cover such events as accidental discharges, occurrences due to power failures, and so forth.

Quality control of wastewater at a high level of reliability requires practical tools which include:

a) continual information about water quality on a suitable "real time" basis.
b) a management and operational system which can respond to off-quality situations and apply corrective actions.
c) quality control facilities that have been adequately engineered to meet extremes in the characteristics of wastewaters.

This paper deals with Item a), the collection of continual information about water quality.

SAMPLING

The objective in the sampling of wastewater is to obtain a sample continuously or to obtain continual samples at intervals frequent enough to describe all events of interest. The samples must also be representative enough to permit adequate accuracy in the final analysis.

The problem of sampling can be minimized if the sensors involved in the measurements can be placed in-situ. There are natural limitations to in-situ placement related to protection from climatic situations or from vandalism or animal damage, and accessibility can be a key problem in suitable maintenance and operation of in-situ systems. Many of the existing procedures applicable to the monitoring of wastewater involve analytical techniques which do not use probe-type sensors and cannot be placed in-situ. For these reasons, many sampling situations require the transfer of a sample by pump and piping to the location of the analytical instrumentation.

SAMPLE TRANSFER SYSTEM

Sample transfer systems must be designed to deliver consistently a representative sample of the water collected at the sampling point. This objective is not easily obtained, for the following reasons:

a) Passage of sample through a pump and transfer line can change the size of solids or distribution immiscible liquids so that solubilization is increased or colloids or emulsions are established.

b) The walls of the pipe provide surfaces on which materials may be adsorbed and desorbed with a resulting change in the distribution of materials in the wastewater sample.

c) The growth of attached organisms in transfer lines is frequently a significant problem. The growth will absorb organic materials from the flowing wastewater stream, and at times the growth may become large enough in quantity to hamper the flow of sample through the pipeline.

Suggested specifications for the sample transfer system are:

a) a submersible pump, such that the sample will be under positive pressure during transfer. Positive pressure will help keep gases and volatile components in solution until the sample is delivered to the analytical instrumentation.

b) The line size should be relatively large (two inches, for example) to minimize the wall-area/sample-volume relationship.

c) The line velocity should be high (five feet per second for example) to provide a significant level of scouring of the pipe walls by the flowing sample. However, velocity alone will not prevent deposit of materials on pipeline walls nor prevent the growth of microorganisms.

d) Because the cleanliness of the pipeline cannot be assured, inspection ports or sections in a line should be made conveniently removable so that the interior of the line can be inspected.

e) Where line fouling by deposited materials or by attached microorganisms is a problem, a back-flush system should be provided. It should have a pressure and velocity capability greater than the normal pumping system. Feed to the back-flush system should be from a reservoir of prepared cleaning solution or disinfecting solution if the situation warrants it.

MULTIPLE TRANSFER LINES

Where analyses of wastewater samples from several points in a system are of interest, it may be practical and economical to transfer the samples from the several points to a single wastewater quality monitoring station. If this approach is taken, it is necessary to interface the several transfer lines with a single sample header, which will deliver the selected sample to the analytical system.

Figure 1 illustrates a sample chest which provides an interface for several transfer lines. Each transfer line discharges a transported sample to a cup. A part of the sample moves forward from the bottom of the cup through a three-way valve, which either discharges sample to waste or directs it to a sample header. The volume of flow from the transfer line is larger than the sample which will flow from the cup; therefore, a significant portion of the transferred wastewater overflows the cup and goes to drain.

The three-way valves are electrically operated in sequence to introduce the selected sample to the sample header for a desired period of time.

SAMPLE HEADER

The sample header provides a flow of the selected wastewater stream from which samples may be taken as input to analytical instrumentation. Several instruments may be supplied by a single sample header.

If compatible with the analytical objectives, conditioning of the sample may be done along the sample header. For example, the sample may be homogenized to create a suitable dispersion of solids or immiscible liquids in the sample. If solids or immiscible liquids must be removed from the sample, either centrifugation or filtration of the sample may be appropriate. However, filtration of a sample may be more practical on a smaller flow directed to a particular analytical instrument.

In any sample header system, there may be interest in collecting grab samples to represent observed peaks in analytical measurements. In order to collect the particular sample of interest, it is necessary to establish a hold-up reservoir in the sample header to provide a time delay equivalent to analytical time delay.

KINDS OF ANALYTICAL SYSTEMS

The discussion of analytical systems is not intended to be all-inclusive, but rather to point to some of the specific kinds of systems which are practical for application to problems of automated wastewater analysis.

PROBE-TYPE SENSORS

There are a number of probe-type sensors which function on the basis of physical or electrochemical principles and which may be placed in-situ or in a sample header to provide analytical information about the wastewater. To date, the application of probe-type sensors has been primarily in water quality monitoring stations. A partial listing of such sensors includes those for measurement of temperature, pH, conductivity, selective ions, oxidation-reduction potential, and dissolved oxygen.

Probe-type systems provide a convenient and relatively inexpensive approach to the continual collection of wastewater quality data. The number of parameters of interest that can be measured by probe-type sensors is limited, and measurement of the presence of organic material in wastewater is not possible with such sensors.

COMBUSTION-TYPE INSTRUMENTS

Industry has developed a number of instruments which function on the principle of combustion of organic materials present in wastewater followed by analysis of the carbon dioxide produced during combustion or of the oxygen consumed during combustion. These instruments have an important place in the analyses of wastewater because they indicate the presence of organic material.

The first generation of the combustion instruments was a total carbon analyzer which passed a sample through a furnace and a catalyst, and then detected the CO_2 in a carrier gas after combustion. The CO_2 either came from the combustion of organic material or was released from inorganic compounds at the higher temperature. The results obtained could be truly representative of the presence of organic materials if the waste stream did not contain carbonates or carbon dioxide prior to combustion.

An extension of the total carbon analyzer was the total organic carbon analyzer, which provided means for measurement of inorganic carbon through acidified release at lower than combustion temperatures and had the ability to subtract the inorganic carbon from the total carbon, either manually or automatically, to arrive at an organic carbon result.

The total oxygen demand instrument functions on the same combustion principle, but the measurement is that of oxygen consumed during combustion. By measuring oxygen consumed, inorganic carbon is not involved upon the release of carbon dioxide. However, there are complications in the total oxygen demand operation because inorganics such as sulfur and nitrogen are involved in oxidation reactions. Sulfur consumes oxygen as it is oxidized to sulfur dioxide. If sulfates are present, oxygen is released when sulfate ion is reduced to sulfur dioxide. If ammonia is present, it is oxidized to nitrous oxide, and nitrates present are reduced to nitrous oxide. The inorganic oxidations and reductions are not fully quantitative, and therefore, are not conveniently compensated for.

INDUSTRIAL PROCESS INSTRUMENTATION

The analytical tools which may be applied to the examination of wastewater quality are not limited to those instruments which have been developed specifically for that purpose. A number of industrial process instruments may be practical and reliable instruments for examination of wastewater quality, particularly if that examination is made at the source. Industrial process systems include photometers for use in the ultra-violet, visible, and near infra-red wave lengths. Since these instruments are designed for industrial purposes, they are rugged and will meet the codes for use of instrumentation in hazardous areas. Industrial process instruments include relatively complex instrumentation, such as on-line gas-liquid chromotography.

AUTOMATED "WET CHEMICAL" ANALYTICAL INSTRUMENTS

Automated instruments are available which, through automation, manipulate a sample through procedures which normally are done manually by a chemist. This kind of instrumentation was first developed for laboratory use to increase the rate and minimize the cost of placing a large number of samples through a particular analytical procedure. The continual nature of the results and the ability of the automated instrumentation to function for extensive periods without operator attention makes automated "wet chemical" instrumentation a candidate for continual monitoring of wastewater quality.

The automated "wet chemical" procedures are primarily those which provide a colorimetric reaction which may be detected by a photometer and related by calibration to the material of interest. However, titrimetric procedures may also be employed. The accuracy of results obtained are equal to or better than those obtained manually by a chemist, and the degree of specificity is as good as can be provided by the particular "wet chemical" procedure.

MISSING LINKS

There are a number of important parameters in water quality for which there are no practical instruments at this point in time for continual measurements. A few of the important areas where analytical measurements are missing are biological stabilization,

micro-biological and biological toxicity, and taste and odor. These parameters represent highly important water quality characteristics. Improved manual techniques and the development of automated techniques are desired.

WHERE TO MONITOR

If an industry is to meet its obligation to have reliable control over the quality of wastewaters discharged, then industry must collect adequate information to define water quality and must collect this information as an input to a carefully designed action program to achieve the desired results.

AT-SOURCE WATER QUALITY MANAGEMENT

Industry should make a careful assay of the control of water quality at-source. There are a number of justifications for at-source water quality control, which include:

- Production efficiency
- Wastewater reduction
- A minimal time-constant for responsive action
- Simplified monitoring
- Optimized overall reliability of wastewater control

The wastewater discharged from a production unit has always received attention related to production efficiency, and industry has in many instances evaluated the economics of reduced wastewater strength through improved production or recovery operations vs. the cost of treating the wastewaters in a central facility.

An industrial sewer normally receives what would be considered to be the normal wastewaters, plus mistakes and accidents. The necessity to provide close water quality management may make it necessary to rethink the service that the sewer should provide. Should mistakes or accidents be relegated to the sewer? or should careful recognition of such events be developed, and alternate routes for disposal be provided?

Control of events which have a strong impact on wastewater quality is probably most practical at the source. If the information about water quality is obtained at the production unit and the alarm for off-quality wastewater is directed directly to the operating personnel (or possibly to an automated correction procedure), then the responsive action to the off-quality situation is accomplished as quickly and as directly as may be possible.

The monitoring of wastewater quality at the source is usually more simple than monitoring wastewater quality on a more complex collection of wastewaters at some point down the sewer. It may be that off-grade water quality can be detected through relatively simple measurements, such as changes in temperature, or in visible or ultra-violet light absorption. If more sophisticated analytical procedures are involved, such as gas-liquid chromotography, a less complicated source sample can improve the reliability of making the specific analysis.

Figure 2 shows a diagram of a photometer (Model 400 marketed by DuPont Instruments Products Division) which was developed initially for industrial process monitoring. Figure 3 is a photograph of the instrument. There are now a number of modifications of this photometer devoted to the analysis of water or air samples. Because of its industrial design, the photometer is particularly suited to use in at-source measurements because it is functionally rugged and is suitable for installation in hazardous areas.

Figures 4 and 5 show a relatively new instrument (developed by Union Carbide and marketed by Ionics) designed for industrial applications. The unit is called DigiChem and is designed to carry out titration procedures on a continual basis. Introductions of samples, diluent materials (which may be either aqueous or organic solvents), introduction of the titrant, discharge of the titrated sample, and clean-up of the titration vessel are all carried out automatically. End-points may be detected by probe-type sensors introduced into the titration vessel, or colorimetric end-points may be detected by photometric examination of a light beam bounced off the bottom of the titration cup. The titration cup is constructed of Teflon.

Ionics also markets a total carbon analyzer (formerly a Union Carbide product) which can be used in hazardous industrial environments through purging of the instrument. This instrument is of the combustion type; however, the carrier gas is nitrogen, rather than oxygen or air, which minimizes hazards if a combustion tube should break.

IN-SEWER MONITORING

For relatively complex sewer systems, monitoring at points along the sewer may be justified. Wastewater characteristics observed in the sewer may be examined to determine the sources of unusual characteristics, and the results may be used to protect and alert down-sewer systems. The need for the in-sewer system may be related to the fact that accidental or purposeful discharges of materials to the sewer do not always occur at the production unit. The discharges may occur in storage areas or as a result of a transfer of material from one point to another via pipeline or wheeled carrier.

The parameters applied to in-sewer monitoring are usually gross measurements such as pH, alkalinity/acidity, total carbon, total oxygen demand, and so forth. For complex systems, it may be worthwhile to provide the capability of collecting grab samples of off-specification wastewaters so that more definite analysis of the wastewater can be carried out manually.

Figure 6 shows the total oxygen demand instrument marketed by Ionics as previously described. The instrument detects the presence of organic and certain inorganic materials by the consumption of oxygen from a carrier gas stream. Samples are continually introduced into the analyzer through an automated injection valve, and results are available approximately every five minutes. The TOD analyzer has

not been offered in a purged housing suitable for installation in hazardous areas. Therefore, the selected location of the TOD instrument must recognize this factor.

Ionics also markets another former Union Carbide product, an organic carbon analyzer (see Figure 7) which measures organic carbon by subtracting inorganic carbon from total carbon. The operation utilizes two independent trains to make the determinations of total carbon and total inorganic carbon, and electronically subtracts the results to achieve a measurement of the organic carbon. The cabinet of the instrument may be purged for utilization in hazardous areas.

TREATMENT PROCESS MONITORING

A very important aspect of any water quality management system will be the collection of adequate information to insure reliable operation of wastewater treatment processes and to record the fact that the effluent as discharged meets legally specified effluent criteria.

The data collected may have the intended purpose of providing automated process control for the treatment facility. Parameters involved may be gross parameters to define process loads, specific measurements to indicate the presence of problem materials in the influent or effluent of the process, or the collection of reaction kinetics and operational parameters necessary for high-reliability control of the process.

Gross parameters may make use of the analytical tools previously mentioned, such as temperature, pH, conductivity, TCA, TOD, TOC, and so forth. Specific analyses may make use of ion-selective probes or automated "wet-chemical" analytical instrumentation.

Figure 8 shows a Technicon instrumentation system which provides capability for routine measurement of wastewater character through automated completion of "wet-chemical" procedures. The system shown in the figure is not intended for monitoring purposes, but it is used in the laboratory for routine analyses under an operator's supervision. Figure 9 shows the modification of laboratory instrument which may be used in the laboratory or in remote locations for continual monitoring of as many as six wastewater quality parameters. Figure 10 shows a later version (Monitor 4) of the Technicon instrumentation directed to monitoring. This instrument uses slower pumping rates to minimize the consumption of reagents and wear on tubing with a resulting improvement in the reliability of operation in monitoring services. The slower operating speed, which is one-quarter the speed normally used in the laboratory, has a disadvantage in that it takes four times as long for any specific analytical procedure to be carried out. The Monitor 4 is packaged in a 2-foot by 2-foot cabinet and is intended for use in relatively rugged environments such as a production area.

The specific analytical instruments may find application in the automated control of wastewater treatment facilities. The Digichem unit mentioned earlier may be applied to the automated

feeding of alkalinity or acidity reagents for pH adjustment in wastewater. This approach may be superior to the current procedure of utilizing pH measurements in feed-back, cascade systems for pH control.

Specific analyses may control the feeding of chemical reagents for specific purposes such as the precipitation of phosphorus or the denitrification of nitrates in the treatment processes.

Biological wastewater treatment processes such as the activated sludge process are expected to remain important among wastewater treatment facilities. This can be anticipated because there are now large investments in biological treatment processes. Furthermore, information presented does not suggest that advanced waste treatment processes will displace biological processes, but rather that biological processes will be used in combination with advanced wastewater treatment methods to achieve water of desired quality.

Since reliable operation of wastewater treatment facilities is necessary to the assurance that the effluent discharged will meet water quality criteria, there is a need for the development of sensors and control systems which can automatically adjust operational factors in the process to achieve the desired result. Such systems do not now exist, but development efforts to provide sensor systems and control stratagems are under way.

Within the activated sludge process, instrumentation and equipment which can pace oxygen transfer equipment in order to supply oxygen in proportion to the demand are available. For those activated sludge processes which receive oxygen transferred from the atmosphere, the level of dissolved oxygen in the system is not a critical factor, as long as oxygen is available. Therefore, the oxygen control systems provide the ability to keep the process aerobic without wasting power through over-oxygenation.

In Figure 11 the elements of a control system are shown. Sensors located in the aeration basins detect the level of dissolved oxygen in the aeration mixture. Through a multi-channel or multi-point operation, the dissolved oxygen information from each basis is acted upon by a logic unit, such that a control sequence to the aeration equipment provides increase or a decrease in the power input to the aeration equipment to achieve the end result of oxygen transfer in proportion to the process demand for oxygen.

Packaging of the oxygen control instrumentation is illustrated in Figure 12. This system is multi-point in that the dissolved oxygen analyzer accommodates six points. In the Weston and Stack Model 3000-S6 Multi-Point Analyzer, switching between points is keyed to the print time of the multi-point recorder. In the illustrated equipment, four aeration basins are under control, utilizing a four-channel multi-point controller system (Weston and Stack Model 8000-4).

When the dissolved oxygen signal from a particular basin is switched through the controller, the status of dissolved oxygen is examined by comparison. The set points and a logic system call for an increase or a decrease in oxygen transfer capacity. The status of oxygen transfer equipment is displayed by lights or by meters on the panel. The particular system (Figure 12) displays the position of the four 2-speed surface aerators in each aeration basin.

Figure 13 shows the Weston and Stack Monitoring Probe Assembly, Model A40/A25. Figure 14 shows a phantom section drawing of the assembly, the top half of which is the probe with anode located internally in the electrolyte and the cathode exposed to the sample through a Teflon membrane. The bottom portion of the sampler assembly is an agitator-cleaner unit, which may be powered by DC, AC, or gas-powered motors. The cleaner-assembly is rotated at about 300 rpm and insures sample transfer in the vicinity of the sensor and a clean membrane so that stable calibration of the system is maintained.

Other than the feeding of pH reagents or the pacing of oxygen transfer equipment, there are few examples of the use of instrumentation for automated control of waste treatment facilities. A number of domestic wastewater facilities have included computer control centers in the design of the facility, but the function of the computers is immediately limited primarily to data logging, rather than process control. The sensor inputs and the logics for control will be developed at some future date and connected to or programmed into the computer system.

EFFLUENT MONITORING

Instrumentation available to monitor the quality of effluents is relatively limited when compared to the criteria which have been applied by many states and which may be expected in any future statements of effluent quality. In the area of organic materials, instrumentation that might be applied is primarily the combustion type analyzers, and of these, the organic carbon analyzer probably has the best potential. The total carbon analyzer is not specific enough, due to the interferences from inorganic sources of carbon, and the TOD analyzer has background problems associated with positive and negative interferences from oxidation/reduction of sulfur and nitrogen compounds. As far as organic carbon is concerned, the desired sensitivity may in many instances be less than 10 mg/l. This level of sensitivity appears to be possible.

Effluent criteria may refer to limits for metals which have toxicity characteristics. These limitations must be related to specific metals, rather than some not-too-definite group, such as "heavy metals". The possibilities of continuously monitoring for specific metals are limited. Automated atomic absorption or atomic fluorescence present possibilities, and there is an outside chance that ion-selective probes may meet some of these requirements. It is also possible to do some of the analyses by wet chemical procedures.

The areas of taste and odor and toxicity are not at this time adequately served by monitoring instrumentation.

CONCLUSIONS

Industry has a responsibility to provide reliable control over the effluents it discharges. It can be anticipated that industry will be required to implement levels of quality control that in the past have been considered as impractical, such as full control over potential accidental losses including discharges at times of power failure. Management of water quality control will require essentially continuous reliable information about discharges of wastewater. Industry should strongly consider making the process unit a key point for wastewater examination. The responsibility for acting upon an event which creates off-quality wastewater should be with the operating personnel. The production unit is also the potential location of suitably responsive corrective action to wastewater problems. Treatment facilities for collected wastewaters may require automated control in order to meet the specified reliability of effluent quality.

Instrumental methods to be used as input to automated control of wastewater facilities are limited currently, but such instrumentation is the objective of research and development projects. It seems relatively certain that in the United States legal requirements for water quality control will be applied at the effluent.

FIGURE 1

SAMPLE CHEST
MULTIPLE TRANSFER LINES

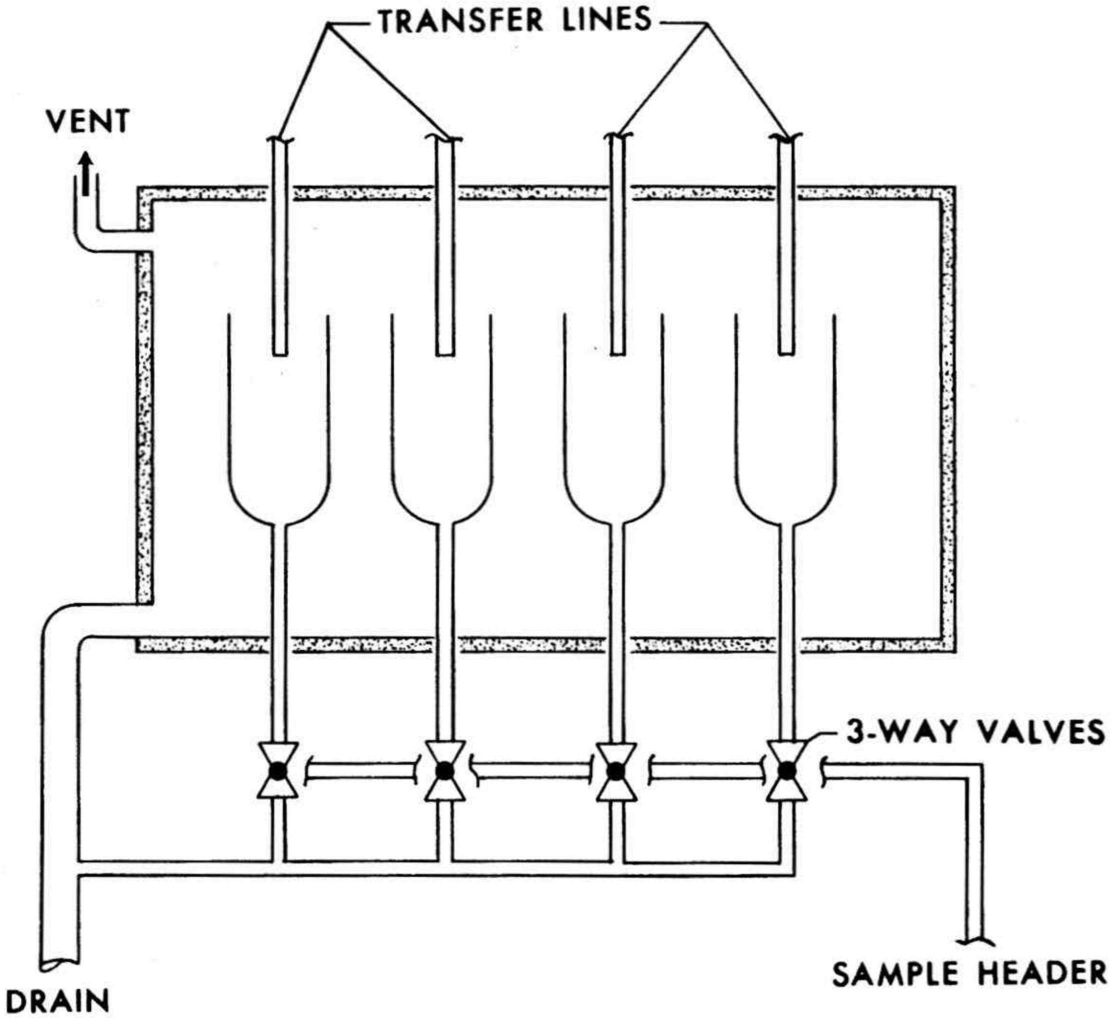


FIGURE 2

MODEL 400 PHOTOMETER
COMPONENT SCHEMATIC

E. I. DU PONT DE NEMOURS & CO., INC.
INSTRUMENT PRODUCTS DIVISION

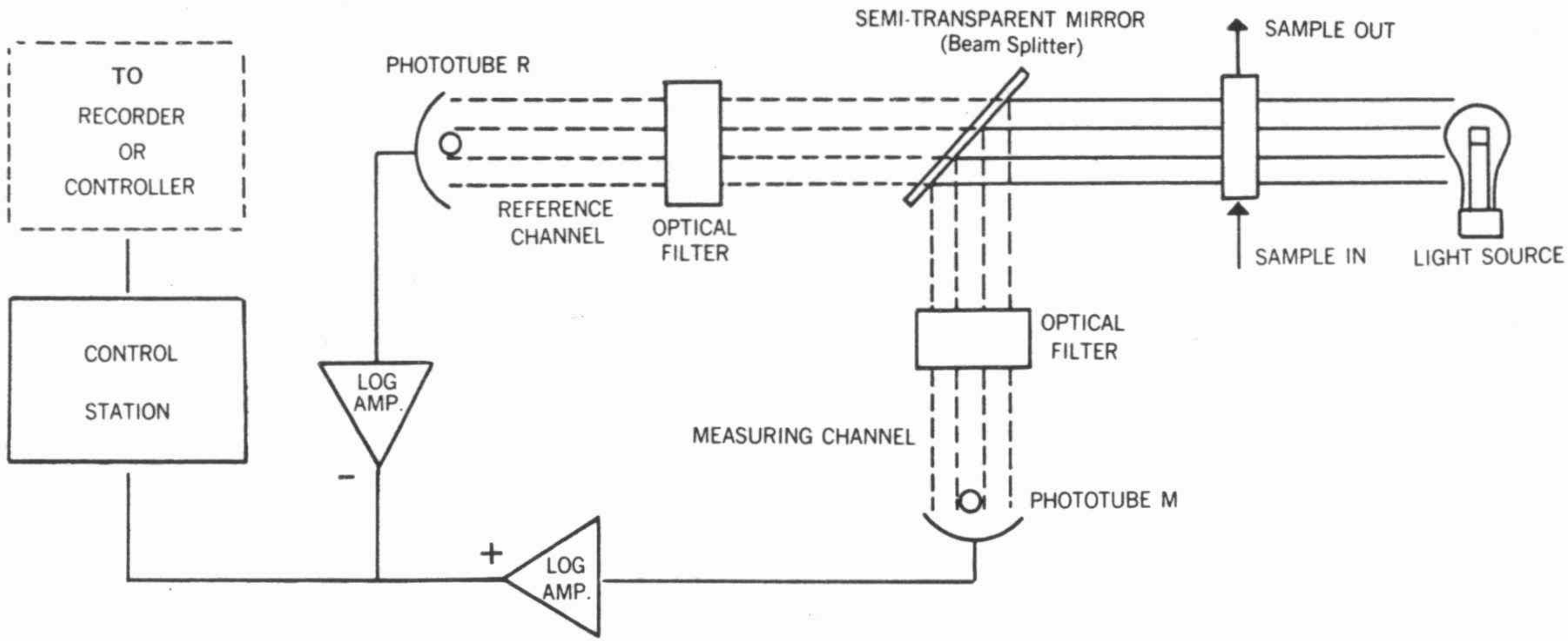


FIGURE 3
MODEL 400 PHOTOMETER
TYPICAL ENCLOSURE
E. I. DU PONT DE NEMOURS & CO., INC.
INSTRUMENT PRODUCTS DIVISION

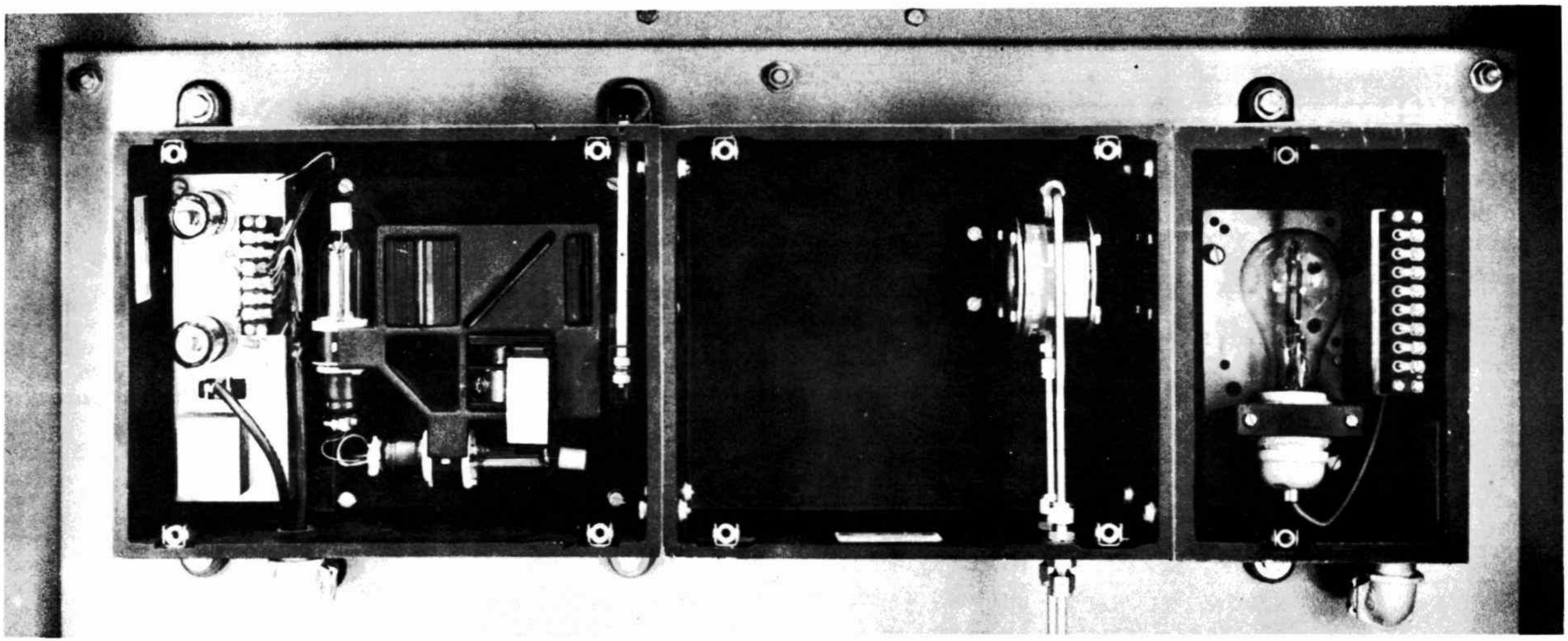


FIGURE 4
DIGICHEM
IONICS, INC.

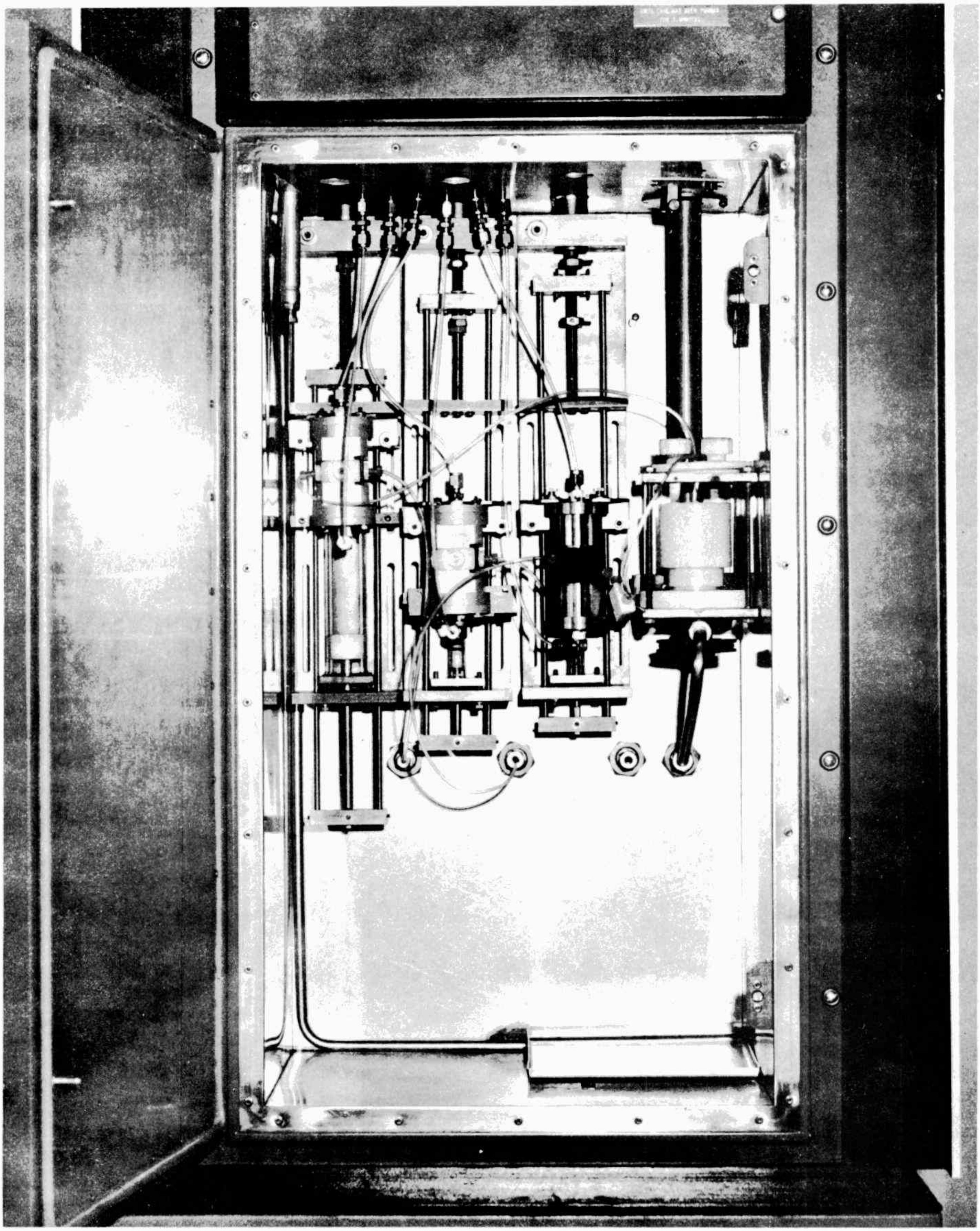


FIGURE 5
DIGICHEM
ANALYZER SECTION
IONICS, INC.

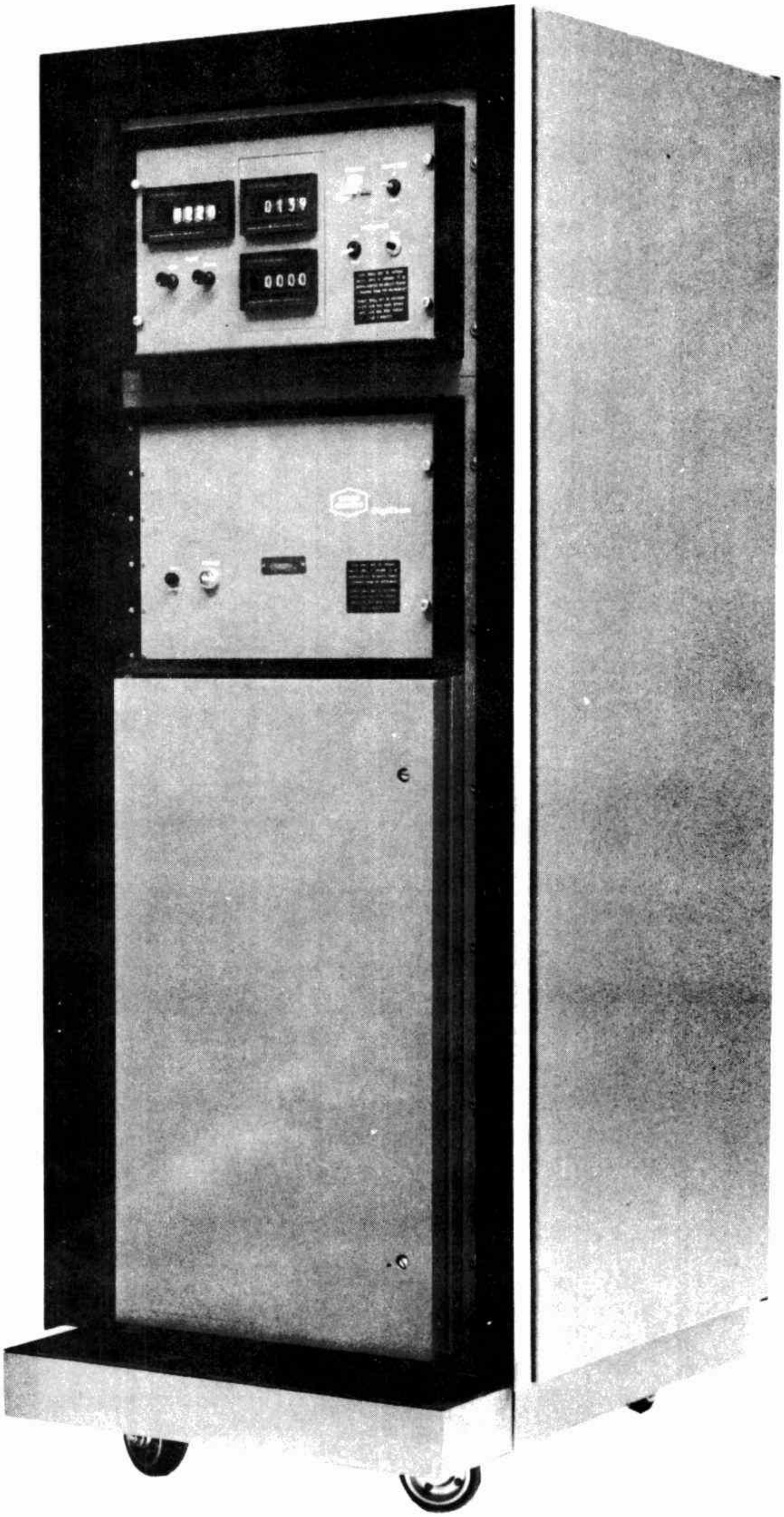


FIGURE 6

IONICS
TOTAL OXYGEN DEMAND INSTRUMENT

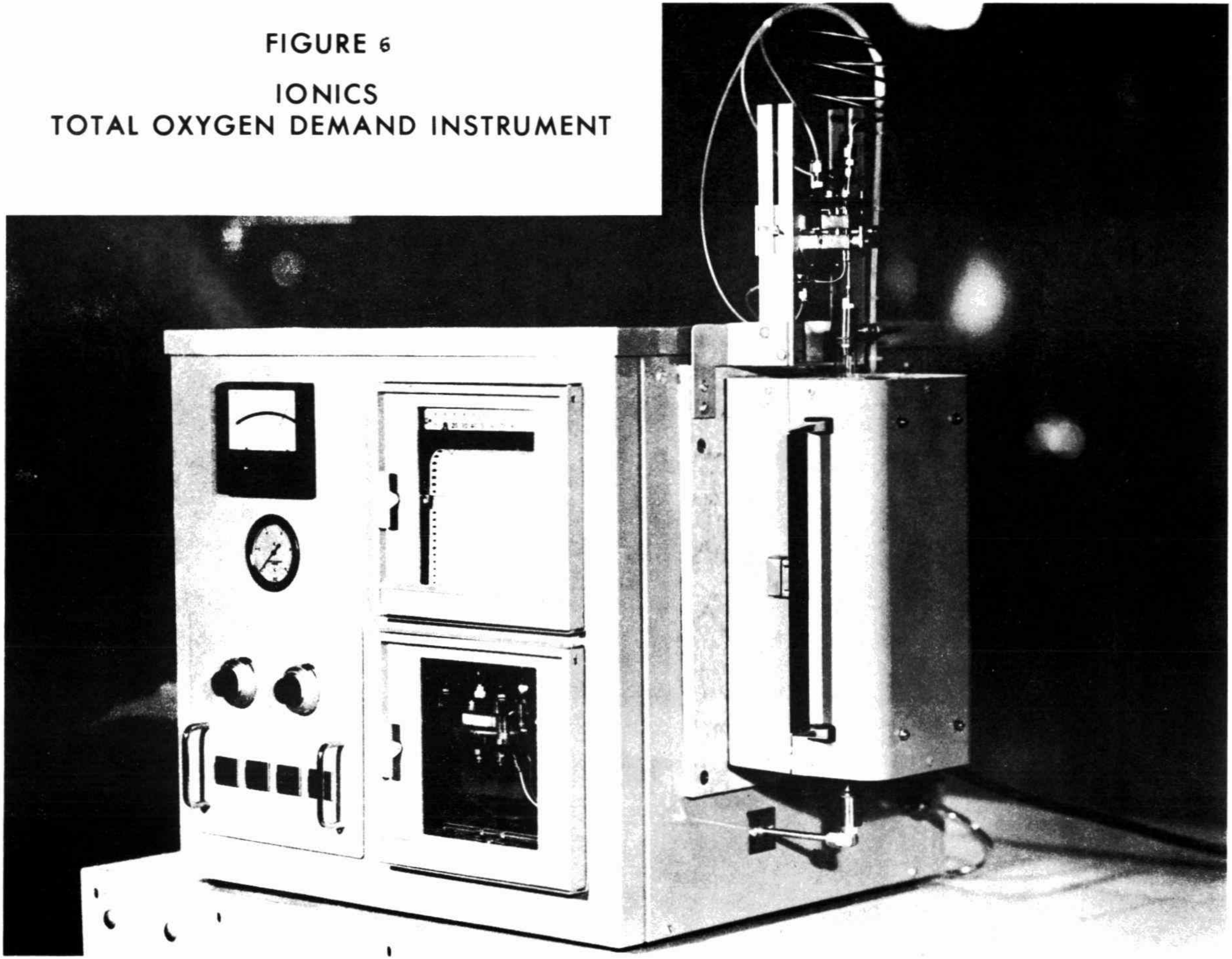


FIGURE 7

IONICS ORGANIC CARBON ANALYZER

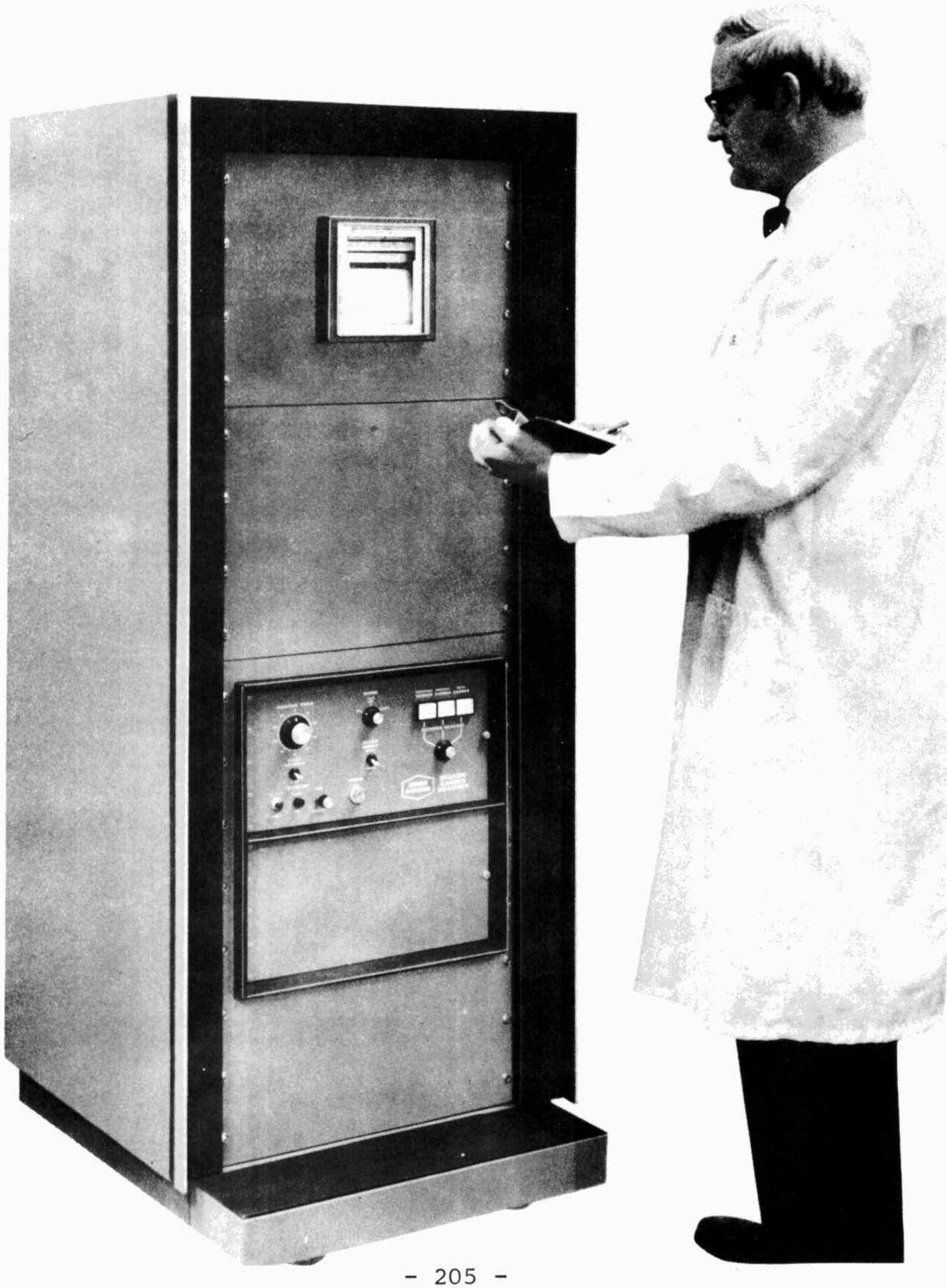


FIGURE 8

TECHNICON II

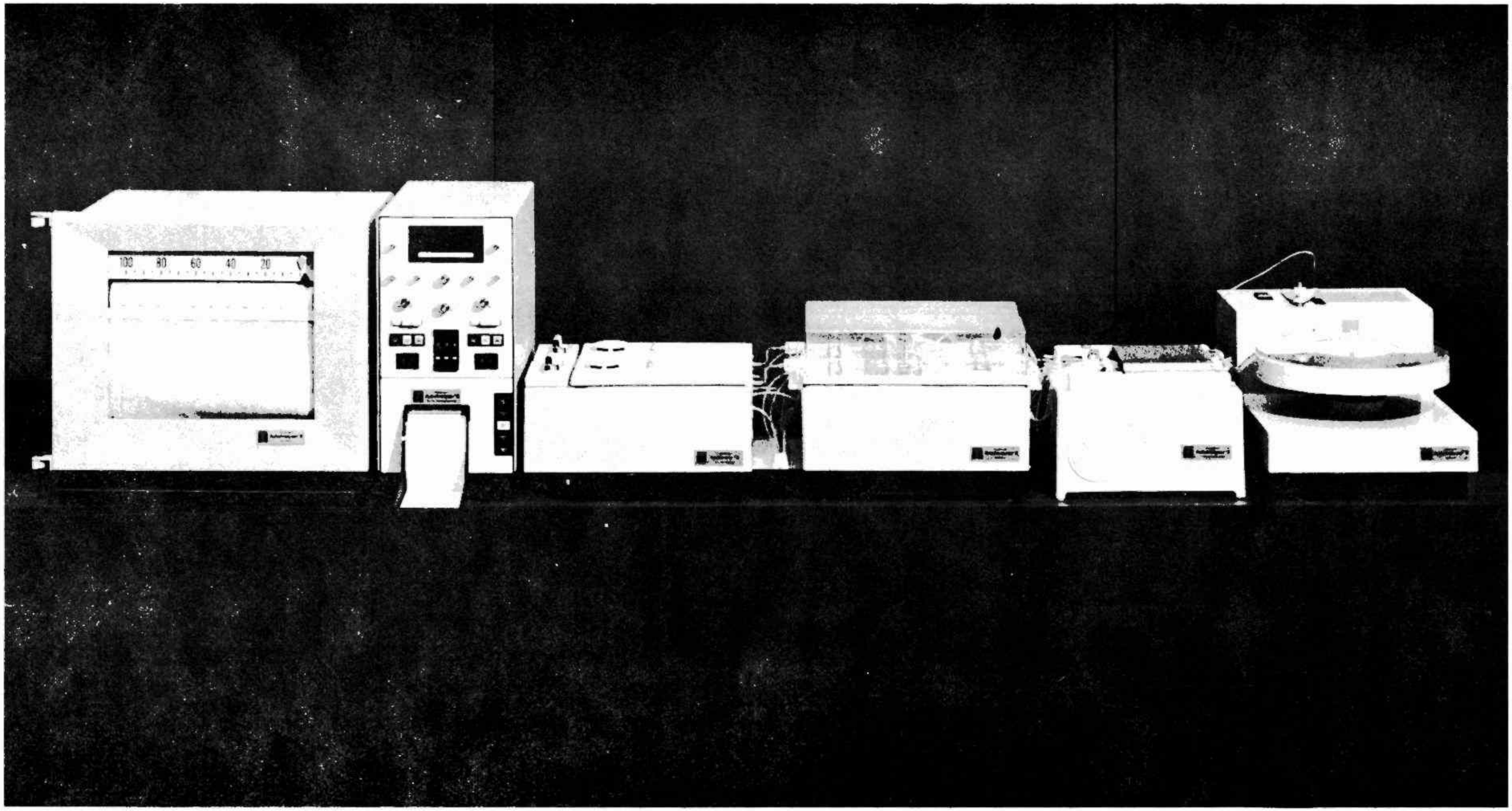


FIGURE 9

TECHNICON CSM6

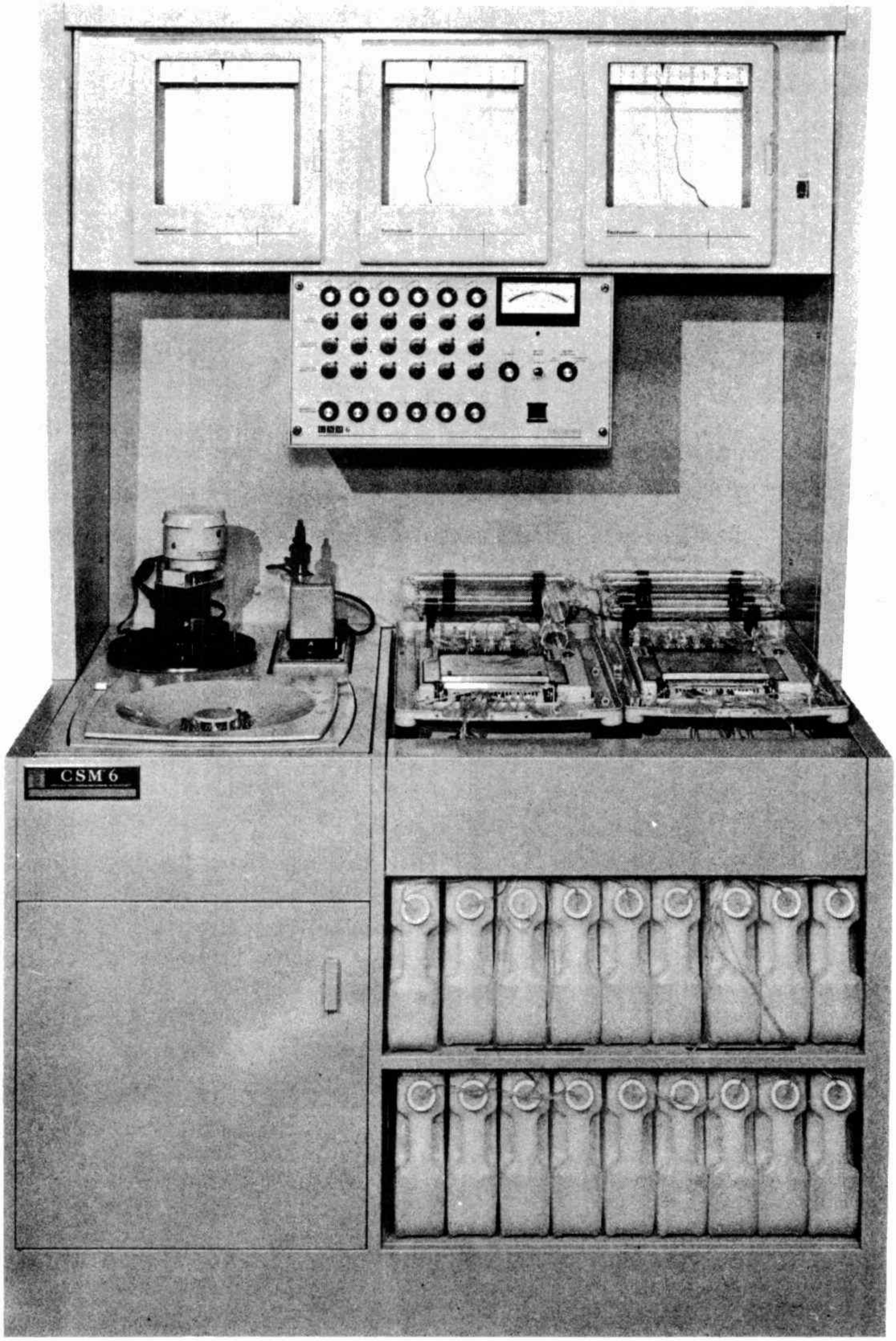


FIGURE 10
TECHNICON MONITOR IV

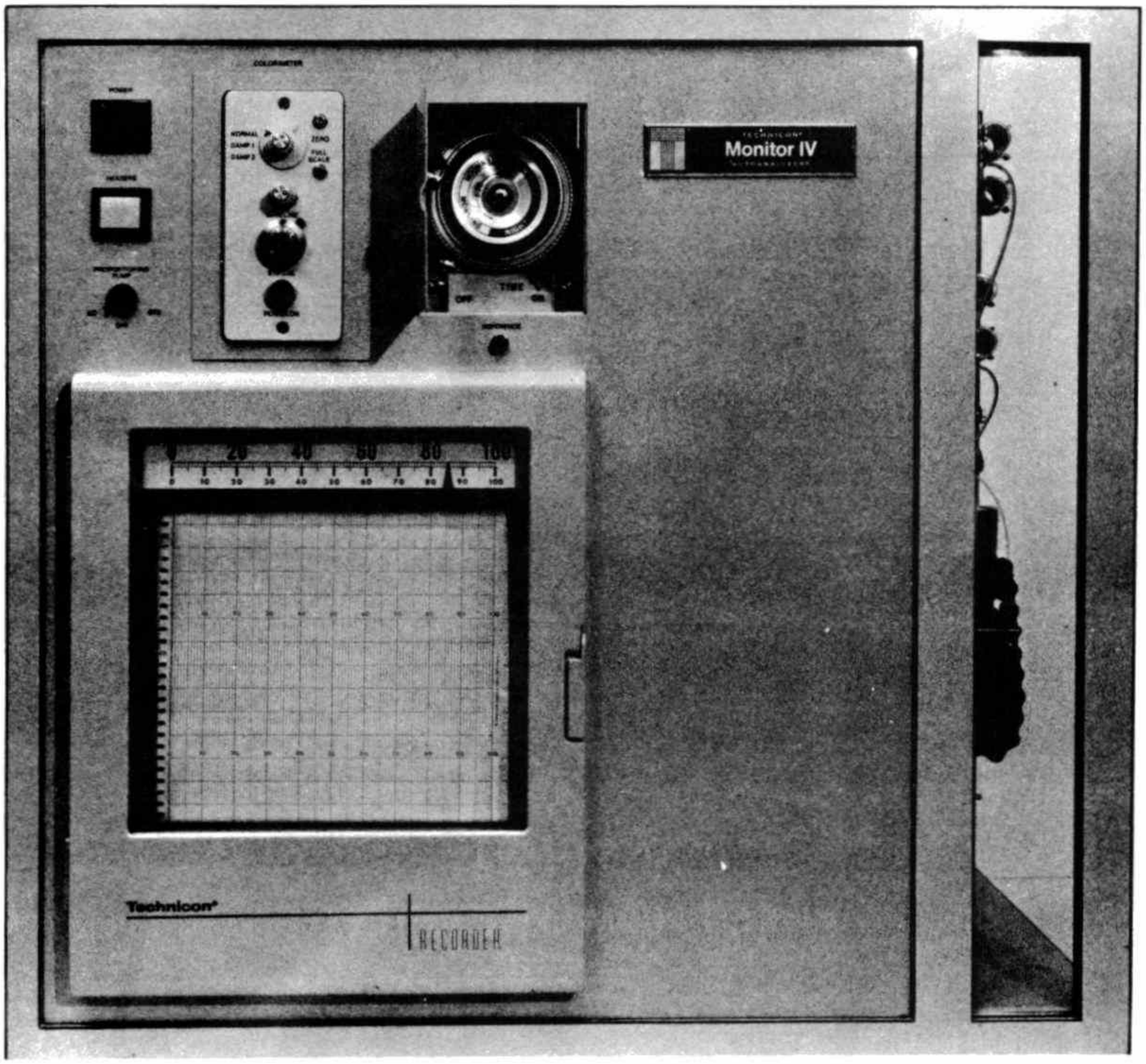


FIGURE 11

OXYGEN MONITORING AND CONTROL

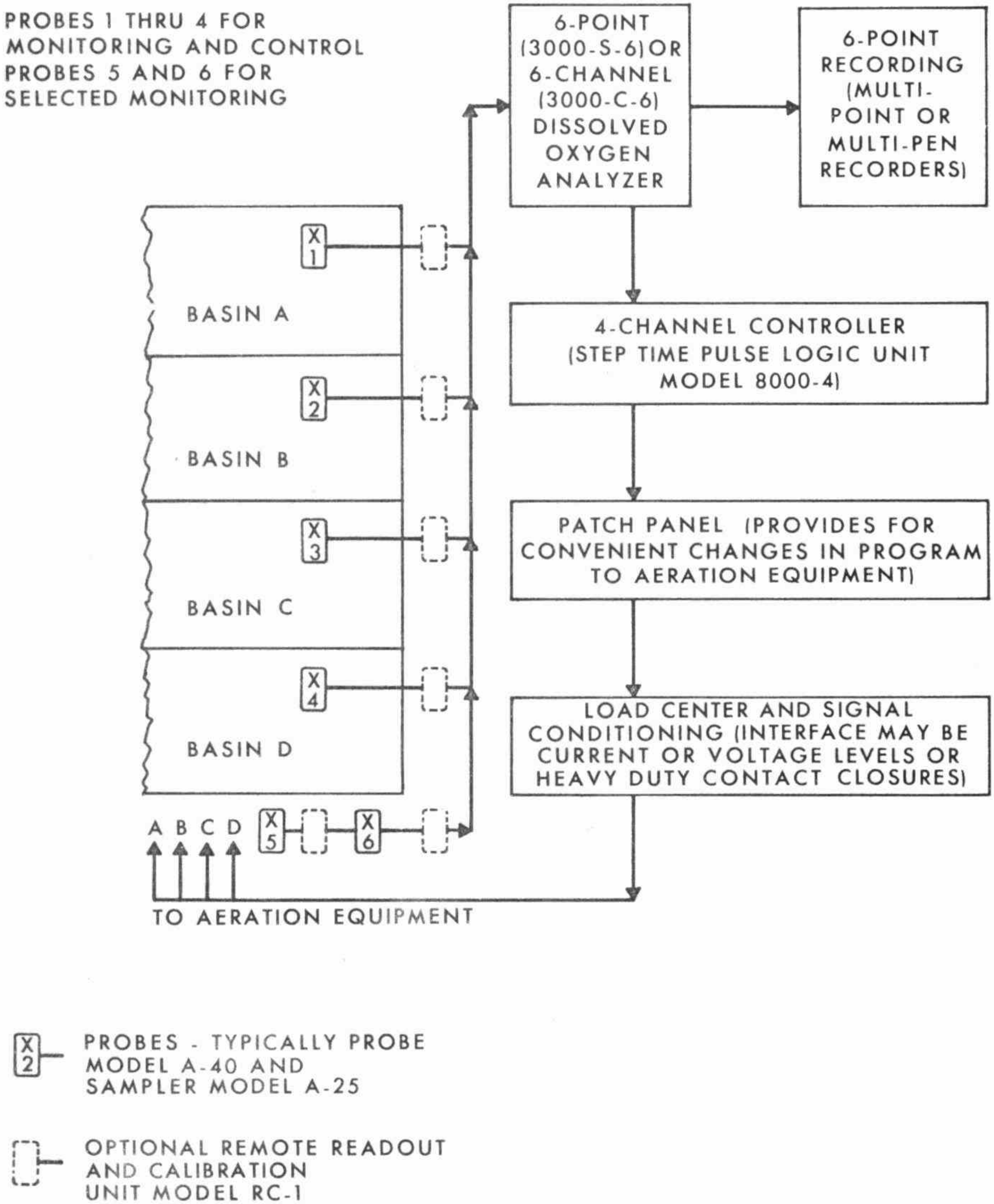
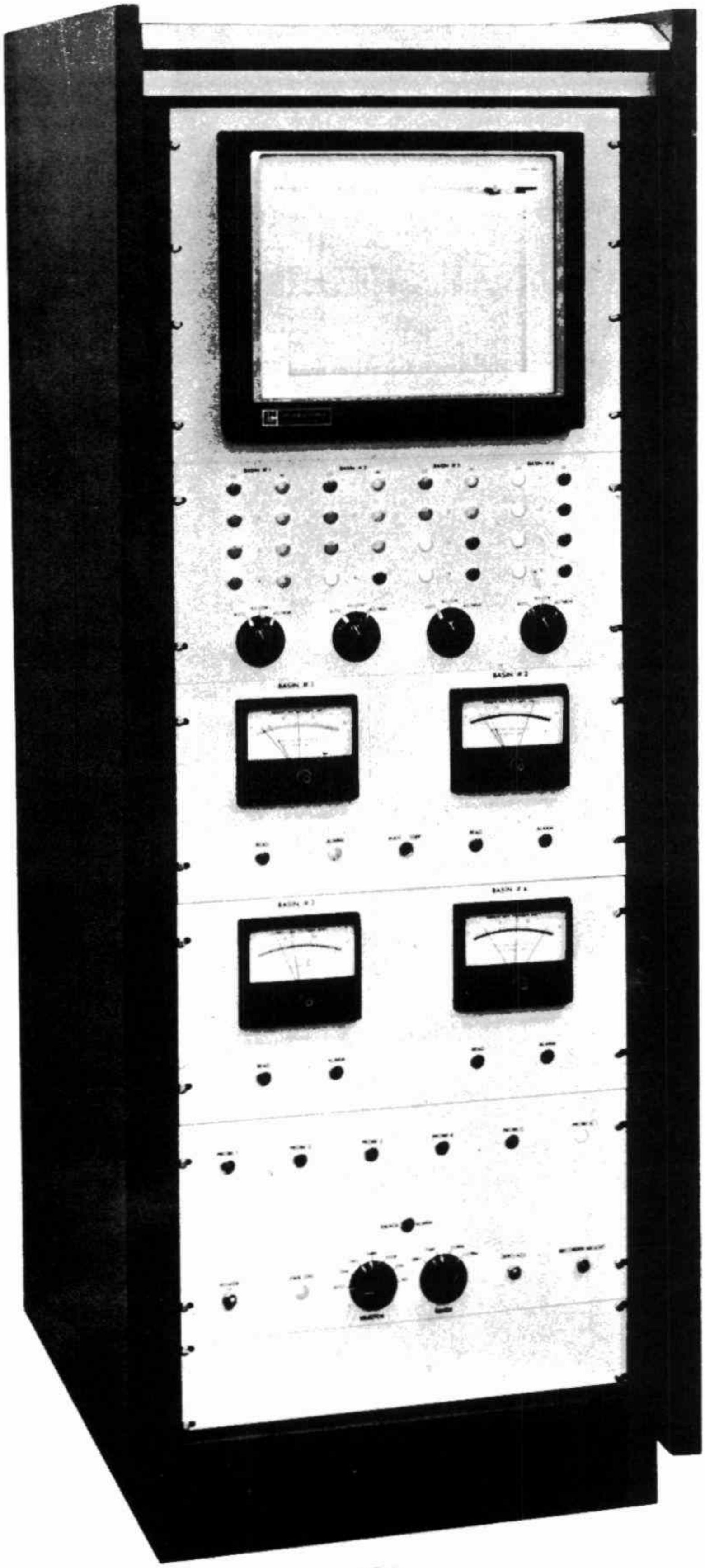


FIGURE 12

WESTON AND STACK OXYGEN CONTROL SYSTEM

ROYAL SERIES CONSOLE



Multi-Point Recorder

Model 8000-4-B

Four Channel STPLU Control Module

Model 3000-S-6-B

Dissolved Oxygen Analyzer (Six points)

Continual printing of Multi-Point Dissolved Oxygen Information (Six points)

Display of Control System Status

Selector switch of Auto or Selected Manual Operation per Channel

Set-point meters for Hi-Lo control selection

Read and alarm lights per channel

Manual step button for single stop manual change

Alarm responds to extended "on high" operating period as selected by the operator

Lights for channel in operation

Alarm if range switch is not in central position

Selector Switches for operating modes

FIGURE 13

WESTON AND STACK MONITORING PROBE

MODEL A40/A25

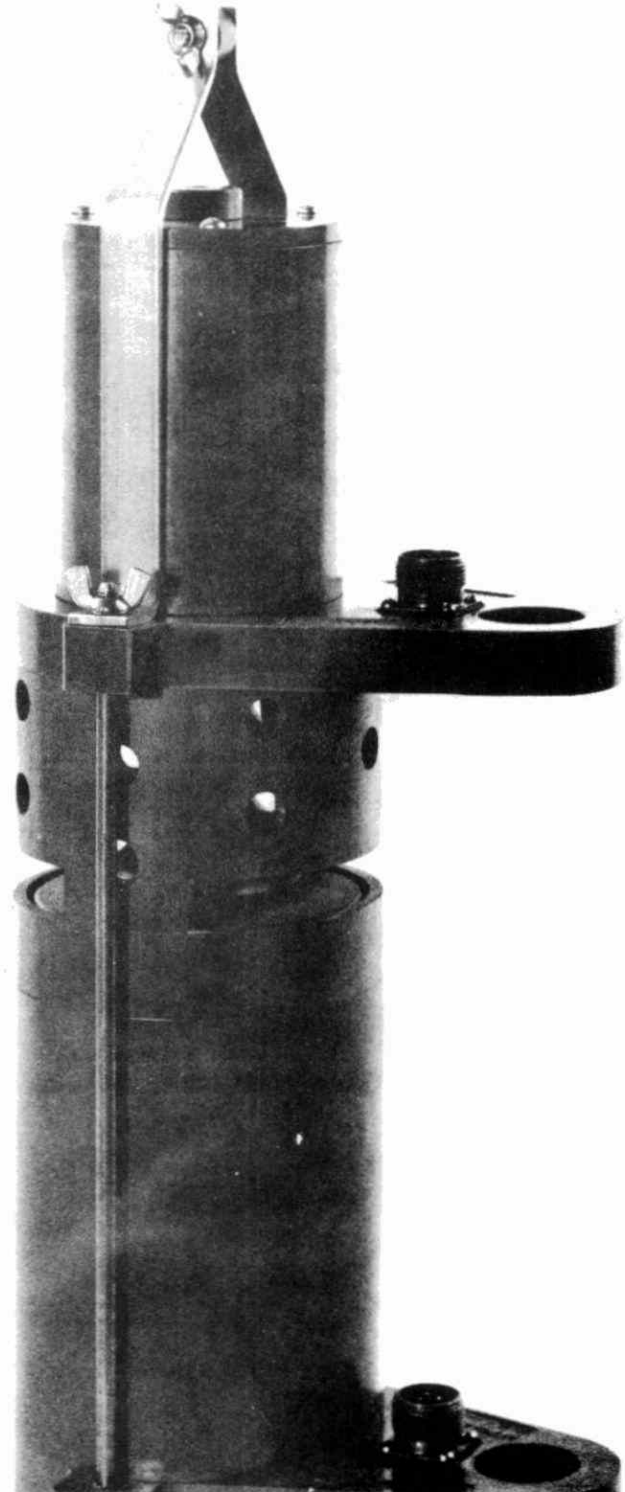
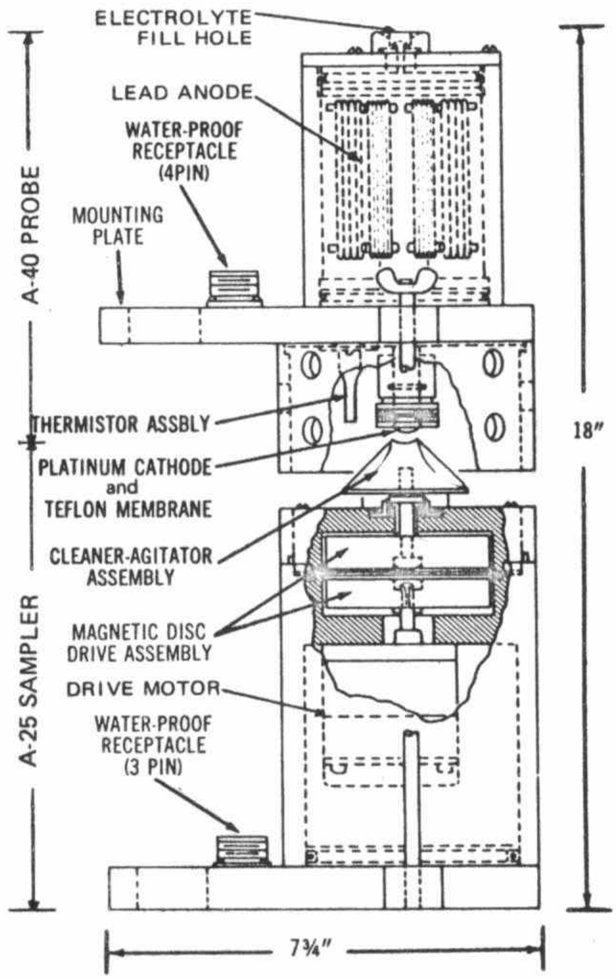


FIGURE 14

SECTION PHANTOMS OF A-40/A-25

WESTON AND STACK MONITORING PROBE



Introducing The Honourable James A. C. Auld, Minister of the newly-formed Ministry of the Environment, and guest speaker at our Conference luncheon of Monday, June 19th

.....

..... delegates attending some of the technical sessions held in the International Rooms of the Skyline Hotel.

..... Mary Lou Collins, nightclub entertainer, and The Art Snider Quintet entertaining guests at the Annual Conference Banquet.

Delegates and wives enjoying the Banquet, held in the Main Ballroom of the Toronto Skyline on Tuesday, June 20th

.....

The Banquet address, entitled

DON'T TRUST TO LUCK

H. S. Rodney

BY

THE REVEREND H. S. RODNEY,
MINISTER

KNOX PRESBYTERIAN CHURCH,
ST. THOMAS, ONTARIO.

Chairman Dave, head table guests and ladies and gentlemen, I am both grateful and gratified to have the privilege of appearing for the second time at one of your programs. It may have been a mistake, but nevertheless I am grateful to receive the invitation and for the very gracious introduction tonight. Last time I was here speaking to your group, I recalled the introduction I received at a Rotary Ladies Night and I have never forgotten that one yet - it has always had a very humbling influence in my life. I was sitting next to my introducer who was toying with his food - obviously not very hungry - and after a while I said to him, "Something seems to be bothering you tonight" and he said in sotto voce tones, "Well, I have to introduce you later". I said, "Don't let that take away your appetite and anticipation" and he said, "No, I didn't mean that, that's one of my problems. I say things which don't seem to come out the way I intended them to. You see, I have three problems: I don't like introducing people - speakers whom I have just met, I don't like getting up to speak myself, and I don't particularly enjoy listening to speakers." So I thought to myself, well I'm away to a good start tonight and a

few minutes after that he was to introduce me and before he got up I said to him, "Well, don't worry about it, just relax and say anything you like and have some fun with it." So he took me at my word, got up and said very simply and very effectively, "Mr. Chairman, Ladies and Gentlemen, on these Ladies Nights in our Kiwanis or our Rotary Club, we always have a speaker of the very first rank and tonight I guarantee you we have the rankest of them all." Ever since that time I've been a little leary of introducers and when I receive a gracious introduction like the one I have just received, I am doubly grateful.

I'm always doubly grateful to be privileged to speak at a Ladies Night although my joy tonight is tempered a little bit because two years ago in June in the same month I was speaking at an international convention in Chicago for Kiwanis Youth and they had there on the bill along with me, or I was along with her or something, Miss Teenage America, and imagine a mere man trying to compete against that and then I received a letter stating Mary Lou Collins was here tonight and I said to my wife, "I'm beaten again." But things happen like that.

I suppose you wonder why a clergyman should be invited to an Industrial Waste Conference. Well, I suppose the real reason is that this is a world in which strange and surprising things happen and that's one of the many wonderful things about it. A Roman Catholic friend of mine was telling me the other day about the priest in his parish who was a young man and who had somehow seemed to have lost interest in his church work. He was just a bit jaded and had lost his enthusiasm so much so that the Bishop noticed it as well as the congregation, although the congregation noticed it first. Then the Bishop noticed it and finally the Bishop called him in and had a talk with him and said, "There's something wrong, you mustn't be feeling well. I think you should go and see your doctor." So he went to his medical doctor and the doctor examined him, pronounced him fit and said, "There isn't anything wrong with you physically, perhaps you have a mental block of some kind. I suggest you go to see a psychiatrist." So he went to see a psychiatrist and after the psychiatrist had talked to him and listened for a while, he said to him, "You know, I think you have only one problem and that is that you are sticking too closely to your church work. After all, you are still a young man and you should get out and enjoy yourself now and then. I want to suggest something to you and I hope you won't be offended. I don't mean any disrespect to the sacred calling of the priesthood, but I think you should leave your clerical collar behind once a month and go out and enjoy yourself, have a night out on the town." So the young priest talked it over with the Bishop, the Bishop okayed it and out he went leaving his clerical collar at home. He decided to go to a fashionable nightclub in the area and as he was sitting there, with one kind of an inducement or another and with a little bit of help, he began to feel a little more relaxed

and he noticed a few bunny girls roaming around the tables, If any of you don't know what a bunny girl is, why I'll tell you after I learned from one of the elders in my church what a bunny girl was. But anyway, one of these girls in particular was going rather close to his table in her journeyings back and forth and she seemed to look at the priest in an unusually friendly way and smiled at him in a happy kind of fashion. After a while, when she had made several trips past his table, he couldn't resist it anymore and reached out and gave her a pat just as she was going past his table. Much to his amazement, she turned on him in great indignation and said, "Well, Father, I'm surprised at you doing a thing like that!". He was completely aghast and said, "What is this Father bit? Do you mean to tell me you know who I am?" and she said, "Why, certainly I know who you are." He said, "Well, how does it come about that you recognize me?" and she said, "Well, don't you know who I am?" He said, "No, I've never seen you before to my knowledge" and she said, "Well, I happen to be Sister Cecilia from the convent next to your church." So he said, "Well, what in the world are you doing here in a nightclub like this?" and she said, "I don't know, I guess we must both go to the same psychiatrist."

Well, a lot of strange and crazy and wonderful things happen in life and I left my clerical collar at home tonight. This being a Ladies Night is always a particularly happy kind of inducement. I've always liked the story of the Anglican Bishop who went out walking in the country one day with his two lovely daughters and they went down to the stream and saw an old fellow fishing there. They watched him for a few minutes, then the fisherman realized he was being observed and recognized the Bishop, and came over to him and suggested that he should try his hand at a bit of fishing for a little while. The Bishop looked at him rather reprovingly and said, "My good man, when I go out fishing on Sundays I am not fishing for the kind of creatures you're trying to get. When I go out fishing, I go out fishing for men." The old fisherman looked at the two lovely daughters and said, "Well, brother, you sure brought along the right kind of bait!" Well, there is certainly the right kind of bait here tonight.

On second thought, I don't think it is so strange that even a clergyman should be invited to a conference such as this because you are concerned with the environment and so am I; you are concerned with pollution and so am I. Since I was here last with your gathering a few years ago in Niagara Falls, the problem of pollution in the world is recognized to be a much greater and a more serious problem than it was even at that time. Perhaps some of you were farsighted enough to visualize the problems of pollution in the immediate and distant future, but now most of

us are sobered and staggered by the thought and there are people who are talking about the environment in a more somber way today. U. Thant, famous for his Secretaryship for many years of the United Nations, has said that unless mankind solves not the problem of war, mind you, but the problem of pollution, man only has about another ten years upon this earth. A writer named Dr. Paul R. Ehrlick wrote a book entitled, "The Population Bomb", and draws a very grim picture of the future in which he points out that if the growth of population continues to outpace (like it is doing now) the growth of our resources or our realized resources to feed the millions and hundreds of millions of people in the world, the future is going to be filled with famines all over the world. However, then he goes on to add that there is an even greater problem and that is the problem of pollution and he says that even if we solve the problem of over-population and under-productivity in things agricultural, we still will have the problem of pollution and this problem is greater than all the wars or possible wars that may occur in the future. And so, as a private citizen, I'm here to simply say thanks to you for the fact that you are meeting, because I feel good to know that there are people like yourselves who are studying this problem and who are earnestly planning and trying to do something about it.

I know in my own experience, and your experience is much greater than mine in this field, how the problem of pollution has grown in a relatively small area in recent years - water pollution, air pollution and all the rest of it. I know that when I went to St. Thomas twenty-eight years ago, one of my favourite pastimes was to go down and fish off the pier of Port Stanley. I know that Lake Erie no longer has pickerel to be found in it - in any areas of it that I know. We are told that part of the reason is pollution, industrial waste, natural waste and sewage, and indeed someone has referred to it unkindly as a giant septic tank yet once it was counted one of the greatest of our lakes. It is reassuring to read that some day it is going to be that way again because there are people like yourselves at work on this problem and other problems of our environment. I have a cottage on the Rideau River, seventeen miles out of the city, five and a half miles east of Kemptville, and when I used to go up there as a boy we could drink water out of the Rideau without any fear of it hurting us, but last year for the first time all the cottagers, myself included, received a letter stating that it would be dangerous for us to eat any of the fish we catch because of mercury contamination. I've seen Ottawa's beaches closed for three years in a row where we used to go and swim in any kind of a stream around Ottawa. I had a friend come up the Ottawa River in a large boat two years ago and he told me it was the last time he was going to come up the Ottawa until it was cleaned up because he had to put his boat into drydock in Kingston for two days to have it cleaned off.

I read of a little girl named Debbie in Vancouver. Debbie fell into an open ditch in front of her house in a suburb of Vancouver and got a strep infection because she swallowed some of the water. She had to be treated with antibiotics for a period of six weeks before the strep infection had cleared up. The first thing that Debbie, who was three years of age, did after she recovered was to go back out to the same ditch and crawl in again - this time feet first - and this time she picked up a series of six infections and had to go on antibiotics for a period of ten weeks. Someone enquired why the ditch was there and they were told it was the cheapest way to dispose of raw sewage and it was a case of pollute now and perhaps other generations can pay later.

If I were to try to preach a sermon tonight, there is a story of a man in the Old Testament named Hezekiah who has this kind of philosophy. Hezekiah was a very fine man in many ways, but he was always concentrating on the present and never worrying too much about the future. Hezekiah made a treaty with a foreign power very antagonistic towards his own government but for some reason of political expediency willing to make a treaty with his country, and when Hezekiah was about to sign this treaty he referred to the fact that this was going to be a great accomplishment in his time as King. One of his closest advisers advised him this was a very dangerous thing to do and that he might be selling future generations down the river and Hezekiah said, "I'm not worried about that at all, what I'm concerned about is that this will ensure peace and prosperity in my lifetime."

Back of the problem of pollution is selfishness. Back of the problem of almost anything I can think of in life is our human nature. Back of the difficulties we have to face day by day, week by week, month by month and year by year in the world, is the fact of our selfishness and the problems we create for ourselves. In the Book of Genesis we are told that when God created the Earth and took a good look at it after those six days and resting on the seventh - today everybody goes for a drive or plays golf, there's no resting, but in those days God rested at least - God pronounced it to be good. Now, we've made quite a mess of it, haven't we? So I say, thank goodness that there are people like yourselves who are concerned about this problem and who are working at it. I am not going to go into the complexity of it or to deal any further with it - simply to say that this is a little parable of all of life, that you are tackling something that is really great, really important, really significant and something that is bound to be costly. You can't have anything in life unless you are willing to pay the price for it. I don't think there are any exceptions to this.

I've chosen as the subject of my address tonight, "Don't Trust To Luck". I borrowed the subject from a book by Lord Beaverbrook, which I picked up in England a few years ago. Lord Beaverbrook wrote the book when he was forty-two years of age, revised it when he was seventy-five and had it re-published. It is the story of his own philosophy of life and this is what he says: "Strictly speaking, in a world of cause and effect there is no such thing as good luck or bad luck; good luck is usually a combination of planning, industry, integrity and hard work, and bad luck is usually a combination of the lack of all of these things. You are not going to be able to solve the problems of mankind or the problems of your own life," he said, "by sitting back and trusting to luck. You are going to solve them by hard work. It's going to cost and cost, but it will be worth it." I think this is something we forget sometimes, that you can have almost anything you want in life if you are willing to pay the price for it.

Did you see the Flip Wilson show when he was speaking to his Negro congregation? He's getting them all warmed up and they are responding to him enthusiastically as he preaches. He is telling them that there's going to be a great day for his little church provided they understand what they have to do to make it a great church. He says that if this church is going to become a great church, the first thing it must do is to become a humble church and if we are going to be humble, then we have to demonstrate it and so I am going to say first of all to you, my people, that the first thing you have to do is to get down on your knees and crawl. The congregation enthusiastically responded, "Let 'er crawl" and then he warmed up to his theme and said, after we've crawled for a while we can't stay down there forever, we've got to get up on our feet and walk. So the next thing I want to say to you is let the church get up and walk and the congregation all shouted, "Let 'er walk, let 'er walk" and then he said after we've walked for a while we can't be content with walking because time is running short and we've got to run and so the next thing I want to say to you is that the church must get up and run, and the congregation shouted back enthusiastically, "Let 'er run, let 'er run." Then he said, however if the church is going to run you are going to have to give more money to the church than you are giving now, so I'm going to suggest that we take up a collection now and see just how much you want to contribute to the church. There was a silence for a few minutes and then the congregation responded with their old enthusiasm as before, "Let 'er crawl, let 'er crawl."

I think this is true of life. You are meeting to deal with something that is a costly business to solve, but the cost of not solving it is going to be even greater. You are meeting to deal with a problem that is tremendous, but your resources are tremendous and

your potential is tremendous. This to me is one of the most exciting things about working with people as I do in the church. I wouldn't want to work on an assembly line. I tried it at one time, but I like working with people rather than things because, you see, people are filled with tremendous possibilities and you never know exactly what they are going to do next. Even the most unlikely people will have great potential often times. In England one night a man sat in his favourite pub very late in the evening and then started home rather inebriated and he was on his way home and took a short cut through a little cemetery. In his inebriated condition and darkness, he slipped and fell into an open grave which was ready for a funeral the following day and after he got in there he started jumping and trying to get out. He became almost panicky when he realized where he was and he sobered up very quickly anyway and started jumping, but he couldn't quite make it. Every time his fingers reached the top of the grave the earth would break away underneath his fingers and he would fall back to the bottom. After a while, he realized there wasn't any hope of him getting out of there by himself so he settled down in the corner to spend the night there. He had just made himself comfortable when he heard a thud and he opened his eyes and a friend of his who had stayed a few minutes longer in the same pub had fallen in at the opposite end of the same grave. So he watched his friend go through the same futile motions he had gone through and then when his friend was standing there exhausted and dejected, he got up very quietly. His friend was standing with his back to him and didn't know he was there and he stepped down a couple of paces down the grave, tapped his friend on the shoulder and said in a deep soporific voice into his ear, "My friend, you can't jump out of this grave", but he could and he did and they haven't seen him since.

Well, I think there's something like this in all of us. We are all more powerful than we imagine ourselves to be really. We have mental abilities we haven't yet used. William James, the father of modern psychology, says most of us never use more than ten per cent of our potential brain power. All it takes is the proper incentive, the proper motivation to bring it out of us. This is one of the great things about life. The problems in life are never here to destroy us - not really. The problems of life are here to stimulate us and the problems you face in your work can be the kind of invigorating and stimulating problems that will bring out of you the best of which you are capable and cause you to look back one day and realize you have made a contribution to life which was worth making. When we get to that place in life and I think we have really arrived, I think this is the wonder of life and the joy of life. I think this is what brings life's real enthusiasm to us. It is the thing of knowing what

we want in life and going out and getting it. This is what success is - the realization of a desired goal. It is achieving and dreaming the dream and then going out and trying to achieve it. You don't always achieve it. The cure is costly and sometimes, admittedly, the cure doesn't work.

I may have told this before to some of you about the unhappy experience of a man who was having difficulties with his wife at home and it looked as if their married life was going to pieces. He went and talked this problem over with his minister and after he had told him the whole story, which consisted simply of pointing out all of his wife's major faults and one or two of his own minor ones (which is the way it's done depending on who gets to you first), he said to the minister hopefully, "Now, what can I do to reform my wife?" The minister wasn't married and didn't have a clue how to reform a wife and he said to him, "I don't know how you can reform your wife, but did you ever think that you might start with yourself?" And this is what we call a revolting turn of events, for most of us don't want to start with ourselves. We'd like to reform somebody else. Well, anyway, the minister pursued his theme. He said to him, "I think that perhaps you could start with yourself, you are one of the unhappiest looking men I've ever seen. I've never seen you cheerful, I've never heard you laugh. If you're like this when you're out on your best behaviour, what must you be like when you go home to relax?" So he said, "I want you to practice the art of being cheerful and let's tackle this problem bit by bit. Try being cheerful even if it nearly kills you and then come back in a week and tell me how you're getting along, and who knows, perhaps your wife will begin to love you once again". Anyway, he went home early from the office this day and he came up the stairs two at a time, singing a happy song as he went. He changed his clothes, got himself all dressed up and came down and told the kids stories at the table all through the dinner hour and kept them regaled with laughter and didn't notice his wife was getting quieter as the evening went on. He was having such a good time enjoying himself he didn't realize the battle flag was flying, but it was just the same. When the dinner was over, he suddenly got up and said to his wife, "You go in and watch the television, I'll do the dishes myself tonight." She went into the living room and sat down and he did the dishes and then came into the living room, picked her up off the chesterfield and swung her around the floor a couple of times and said, "Let's go dancing, boy, do I feel like dancing tonight!" Now, he overplayed his hand a little bit bit because marriage takes the dance out of many a man and he should have known that, but again he was having a great time enjoying himself. However, his wife didn't seem to respond particularly and he took a good look at her for the first time in a little while and suddenly discovered that she

was crying as if her heart were broken, and completely beaten and baffled he stepped back and said, "For Heaven's sake, what's the matter with you now?" She looked at him, wiped away her tears for a moment, regained control of herself a bit and then said, "You want to know what's the matter with me and I'm going to tell you. I've had a terrible day all day and I've had a headache, the children were unmanageable, everything was wrong and you came home from the office in the middle of the afternoon dead drunk and you ask me what's wrong!"

Well, if you are not cheerful by nature, lead up to it gradually. You know, even the best of cures don't always work, but it's still worth the trying. This is the thing that brings some enthusiasm to life. This is the thing that makes life rich and meaningful for every one of us. When I think of enthusiasm, I can't resist a little poem which I probably have repeated to you before. It's the story of a minister who, after he retired from the ministry, wrote a little book of poems. His name was Oral Breeze and he is now the Clerk of the Town of Endicott, New Jersey. He was in the ministry for about twenty years and decided to go straight and got himself a job. After he got this job he started writing some poems about things that happened in his little church and he disguised the name of the place and called it Spudville, but apart from that he tells me that it's all very true and he gave me this poem. Incidentally, it's on the subject of enthusiasm, and says:

Most every church has one or more of Earth's uncalled-for
jewels
In vulgar parlance called old maids, some call them wives
some fools
But I'm not here to argue that or give advice or warning
I only want to tell you about what happened Sunday morning.
It seems that old Joe Martin's gal and her beau, young Jim
Brown
Decided Sunday to get hitched and so drove into town.
They hunted up the Reverend Jones and told him why they'd
come
And Reverend thought he saw a chance to boost church
interest some.
He said if they'd agree and wouldn't feel too nervous
He'd like to tie the nuptial knot at the close of a morning
service.
So they agreed and came to church and none of us was wise
Because the Reverend wanted to give us a big surprise.
He preached on seek and ye shall find, it would make your
heart rejoice
And considering what followed some sure thought it sound
advice,

For when he finished preaching he said he had a stunt
That likely would amaze us and he stepped down in front.
For those who wish to wed step up, said he, with his best smile
And fourteen women and one man came rushing down the aisle.

That's what I mean by the spirit of enthusiasm. Well, I'm going to leave you with that. May you be enthusiastic even about the problems you have to face in a conference such as this and in your daily work. May you be enthusiastic about life, for basically it is a wonderful, great and good thing. May you find much to dream about, much to laugh at and don't take yourself too seriously, for when you do you destroy any opportunity to take your work seriously. You're thinking too much about yourself and it's true that any one of us when we get wrapped up in ourselves, makes a mighty small parcel. But God has given us the gift of life, so use it. Use it to look up and laugh and believe and build and dream and create. Some day by the grace of God, this great and wonderful and beautiful old world of ours will blossom beautifully and sweet and clean again and you can help to make it so. Thank you very much.

SESSION CHAIRMAN,
MR. F. A. BAIN,
DIRECTOR, ENVIRONMENTAL CONSERVATION,
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INDUSTRIAL WASTEWATER TREATMENT PROGRAM AT THE FORD-WINDSOR COMPLEX

BY

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INTRODUCTION

Ford, like the rest of our society, became increasingly aware of the need to improve our environment in the early to mid-1960's. As we investigated our facilities, it became obvious that major pollution control programs would be required at the Windsor Complex. This evaluation was confirmed when an unsolicited report dated March 10, 1966 was received from the Ontario Water Resources Commission titled, "Industrial Wastes Survey of the Ford Motor Company of Canada Limited."

Reports such as the one received on the Windsor Complex are obviously greeted with mixed emotion, but they serve purposes. They inform an industry of the basic facts of the situation and the general expectations of the regulatory agency. Such reports also give the regulatory agency an insight into the workings and conditions of the industrial plant.

INDUSTRIAL WASTE SURVEY

The Windsor Complex consists of two machining plants, an iron casting plant and an electric utility powerhouse, all constructed in the 1920's and 1930's. This Complex is shown on photograph 1. The wastewater treatment program began with an industrial wastewater survey which included unravelling the nearly half century of plumber's laissez-faire. A study was undertaken to identify the volume and uses of water and the sources and character of waste streams emitted from various portions of the plants. A consulting engineering firm was retained for this investigation in 1966 and they completed their report in July 1967. This survey included a water balance of the total Windsor Complex.

One has to approach a complex such as at Windsor with an understanding that if wastewater has to be treated to remove impurities, it ceases to be free of cost regardless of how unlimited in quantity the millwater intake source may be. In complexes with unlimited sources of millwater, the oil concentrations at the river can be deceivingly low because of the large volumes of cooling water which both dilute the oil and cause it to float making representative sampling very difficult to perform. For example, at the Windsor Complex the net ether extractable (oil content) between millwater and effluent to the Detroit River rarely exceeded 10 milligrams per liter (mg/l) in the 44-50 imperial million gallons per day (IMGD). (All further references to gallons are imperial gallons.) Such a value, however, represents between 4,400 and 5,000 #/oil/day if all the ether extractable was oil. Conceivably much of this oil eventually rises to the river surface and gives rise to the common oil iridescence. The approach is a turning away from strict interpretations of the chemical analysis of oil at the outlet to the river and instead giving attention to the more concentrated oily waste streams from the industrial processes. This approach requires more investment in process sewers but does result in reduced sizes of treatment facilities.

The Ontario Water Resources Commission report of 1966 and the investigations by Ford indicated that the principal pollutants from Windsor Complex were oil, suspended solids, and traces of phenols. The general findings are shown on Figure 1. As can be seen, the oil largely originated from relatively low flows from the machining plants while suspended solids emanated largely from the Windsor Casting Plant dust collection systems.

OILY WASTE TREATMENT PROGRAM

Sewer Separation Program

While the two machining plants (originally an Engine Plant and a Transmission & Chassis Plant but now two Engine Plants) had made every effort to maintain good housekeeping and contain oil, amounts of emulsified oils were lost to the storm sewers through direct connections, overflows, leaks and stormwash. Typical sources of such oil are:

1. Industrial washer overflows & dumps
2. Spent emulsified oil coolants systems
3. Hot test stands
4. Oil mist & dynamometer wet air scrubbers
5. Mop carts, steam clean booths, degreasers
6. Oil drainage from waste chips, drums & machinery.

Since the building roofs are irregular, the roof drainage by necessity is collected in the valleys and drained to underground storm sewers through numerous vertical downcomer pipes attached to columns throughout the plant. This resulted in a proliferation of small storm sewer branches throughout the plants which, over the years, were also utilized to dispose of process wastewater.

Inplant oily wastewater collection systems were designed and installed in the two Windsor Engine Plants. These collection systems consist of numerous floor sumps and pump stations located at sources of wastewater. Drainage at individual machining areas is controlled by the depressed floor areas, curbs and/or gutters. Wastewater discharge is pumped into an overhead piping arrangement and into a header pipe which discharges to the industrial waste treatment facility. Concentrated emulsified oil coolant solutions are pumped to a central holding tank where they can be returned for reuse or metered to the waste treatment facility. The engineering design of the above facilities was undertaken by the Ford Windsor Engine Plant personnel. The design required careful investigation to (1) insure all oily waste sources were collected (2) minimize the interruption to production during construction and (3) install facilities which would not fail to operate due to hydraulic overload, debris or pump breakdown. This program was completed in May 1970.

Control of Outside Sources of Oil

Yard areas are an often overlooked source of oil and the control of such oil losses probably represents one of the most difficult and costly control problems. Oil drainage resulting from leaks from outside storage of drums and machinery often is washed to the storm sewer. Oil also can drain or be washed from outside storage of waste metal turnings and chips. Curbing of such areas creates serious problems of vehicle ingress and egress in addition to poor drainage and ice hazards in winter. The approach utilized at Windsor has been to confine the activities within the manufacturing building and to install roofs over the outside work areas. With this arrangement, mixture of oil and storm runoff is minimized and the oil drainage can be directed to the wastewater treatment facility without serious hydraulic overloading problems. One of the two shelters over the chip work areas is shown in photograph 2.

Also under consideration at the present time is a 1.0-1.25 acre oil polishing lagoon which would be located near the Detroit River and would serve to remove any iridescence on dry or wet weather flows. This lagoon would provide several hours retention time to the 15-20 MG dry weather flow from the Engine Plants and the Casting Plant. Such oil films appear inevitably to occur in the wastewater discharges at large manufacturing complexes even with the best intended treatment. This lagoon also would serve to protect against any oil spillage from accidents.

Normal Oily Treatment Processes

The oily waste treatment process at Windsor has evolved into an excellent method of treatment without the formation of large volumes of sludge.

Before describing the oily waste treatment at Windsor in detail, it is appropriate to first outline our general experience and practice in normal oily waste treatment.

In new machining plants it has been common to convey relatively low volume, but concentrated spent coolant solutions, having an emulsified oil content of 20,000-100,000 mg/l, to the treatment plant separate from the more general oily waste stream which originates largely from industrial washer overflows. This general oily waste stream represents about 90-95% of the total wastewater volume and has an emulsified oil content of 500-3,000 mg/l.

The coolants are normally treated in 24-48 hour batch treatment tanks with calcium chloride at a temperature in excess of 150°F. to make a primary oil emulsion break. The general oily waste stream, and the water phase from the coolant break, are collected and treated with ferric chloride and lime (or caustic) to cause precipitation of ferric hydroxide which then absorbs the emulsified oil. The resulting sludge is settled in a clarifier and the treated water overflows a weir and is discharged to the sewer. The settled ferric hydroxide sludge, with 2-3% oil content, has always represented a most serious technical problem to dewater and dispose of off site. The magnitude of this problem is dramatized when it is recognized that to remove 1,000 gallons of emulsified oil from 1,000,000 gallons of wastewater, a sludge volume of 5,000 to 20,000 gallons is produced. This sludge is normally 1 to 2% solids.

It has been our consistent goal to develop an efficient oily waste treatment process which minimizes or eliminates the attendant sludge problem. The oily waste treatment process at the Ford Windsor Complex appears to have largely accomplished this objective. Since the treatment is related to many factors perhaps unique to Ford operations, particularly at Windsor, the possible adaptation of this treatment technique to other process wastewater and locations should be carefully evaluated to insure adequate treatment will be provided.

Because of the variations in the chemical character and flow rates of the oily waste stream, which is a "witches' brew" in the most polite terms, all new oily waste treatment facilities are designed with batch receiving tanks to allow collection of oily wastes over an extended period of time. Such facilities allow the operator to obtain a representative sample for evaluation of the wastewater character. Such a treatment approach is essential to insure that proper chemical dosages are established and applied to the treatment tank. It further allows the operator to innovate a treatment process which best meets the particular needs of a location and time.

Windsor Complex Conditions

The situation at Windsor presented a somewhat different situation than is normally experienced. First: no process sewer originally existed in the machining plants and it was felt that only a single process sewer should be installed. Coolants would be collected in inplant storage facilities for potential reuse but spent coolant would be discharged to the general oily waste stream. This would result in an unpredictable mixture of the concentrated coolants and the general oily waste and result in wastewater with oil contents in the range of 500 to 25,000 mg/l. Second: the oily waste flow rates could not be precisely established at the time the program was under development and this could result in improper sizing of treatment facilities. Third: it was known that relatively large sedimentation facilities would be required for treatment of the wastewater at the Windsor Casting Plant but these facilities would not be operational until about 12 months after the scheduled oily

waste treatment plant was placed in service. The most logical approach would be to initially plan an oily waste treatment process which would not produce any oily waste sludges, but if additional future treatment similar to other Ford oily waste treatment facilities was required, the sludges would be discharged to the Casting Plant clarifiers for sedimentation and disposal. This would have the advantages of both reduced capitalization and consolidation of facilities and improvement in the dewatering characteristics of the oily ferric hydroxide sludge which would be only a fractional portion of the wet solids removed in the Casting Plant clarifiers.

Windsor Oily Waste Treatment

The Windsor oily waste treatment consists of three 200,000 gallon waste treatment batch tanks equipped with acid proof lining, air mixers, and oil skimming troughs. Calcium chloride, sulphuric acid and caustic are stored in three 6,000 gallon storage tanks. Skim oil, which is removed from the treatment tanks, is directed to 2-10,000 gallon steam heated tramp oil tanks where oil is concentrated and directed to a 10,000 gallon storage tank. Water, separated from the tramp oil, is returned to the waste treatment plant influent wet well while the tramp oil is hauled to the Ford Powerhouse for burning with primary fuels. The oily waste treatment plant is shown in figure 2 and photograph 3.

Sulphuric acid is mixed with influent untreated wastewater to lower the pH to a 2.0 to 3.0 range. This usually requires about 150 gallons of 95% sulphuric acid. The tank under treatment is air mixed for several minutes to homogenize the wastewater. The treatment tank is allowed to stand quiescient for 6-12 hours to allow acid digestion of the emulsifiers. Contents of the tank are then jar tested to establish the proportion of 35% calcium chloride and 50% caustic soda required for emulsion breaking. Usually 150-200 gallons are required of each chemical for each 200,000 gallon batch treated. Final pH of the treated wastewater is 7.5 to 9.5.

An unusual feature of the oil waste treatment facility is an automatic controller which regulates both the valves and treatment sequence. This controller allows the tanks to automatically fill and be treated with sulphuric acid during unattended periods. The controller also can regulate the timing for tank mixing, caustic neutralization, oil skimming and tank drainage during attended shifts. The controller program can be manually delayed or interrupted during treatment periods by the operator as conditions require.

The emulsion break requires the sequence of operation just described with an abundant source of soluble calcium ion available. Quantities of suspended solid particles of iron and aluminum are dissolved and flocculate as low volume, floating precipitates to be removed with tramp oil. The water phase is distinct from the oil phase and is clear of turbidity with a slight orange color. The light color is believed to be an organic or iron complex dye which can be largely removed by reducing the final pH.

Approximately 200,000 gallons of wastewater are treated daily during the second shift. On the treatment plant initial startup the treatment of emulsified oils was erratic, swinging from good results on one day to disappointing treatment on other days. Over a period of time; with the combination of batch treatment and dedicated operators, procedures were developed which better identified the difficulties of treatment and methods of improved treatment.

Over the 24-months that the plant has been in operation, a high level of oily waste treatment has been achieved without the formation of large quantities of the oily waste sludge. The small volume of precipitates which act in the emulsion breaking process float to the top of the treatment tank and are removed with the tramp oil. These precipitates, consisting largely of iron and calcium together with inert silica, are mixed with the tramp oil and burned. A portion of this material separates below the tramp oil and is returned to the main treatment tank. This recycling of this accumulated precipitated material has been established as an important factor in achieving good oil emulsion breaking and in causing flotation of suspended solids and newly-formed precipitates. This is an essential requirement at Windsor because no sedimentation and associated sludge handling facilities have been installed. It is expected that over a period of time it will be necessary to remove an additional amount of these precipitates from the system.

It is important to recognize several factors associated with the oily waste treatment process used at Windsor. First, the level of dissolved solids is approximately double the dissolved solids concentration of conventional oily waste treatment. Second, a light orange color is produced in the wastewater which in some circumstances would be objectionable. Third, the contamination of tramp oil with quantities of iron and calcium precipitates and inert silica has not been viewed with concern since the tramp oil is burned at the Ford Windsor Powerhouse. Analysis of the tramp oil indicates a pH of about 3.0 with the water content varying from less than 1% to more than 10%. The major contaminants are iron and calcium.

Oily Waste Treatment Efficiency

Table 1 depicts the overall operating efficiency of the oily treatment facility.

TABLE 1
SUMMARY OF OIL WASTE TREATMENT

Parameter		Treatment Influent	Treatment Effluent	Intake River Water	Total Complex At River
Ether Soluble(1)	mg/l				
Average		21,225	6.0	0.8	2.5
Maximum		49,050	21.5	3.0	13.5
Minimum		2,700	1.5	0.0	0.0
Suspended Solids	mg/l				
Average		-	13.1	(3)	(3)
Maximum		-	44.0	(3)	(3)
Minimum		-	2.5	(3)	(3)
Other		440 (2)	-	-	-
pH		8.5 (1)	9.0 (1)	-	-
Dissolved Solids	mg/l	1,700 (2)	3,500 (2)	-	-
Phosphates	mg/l	50 (2)	0.01 (2)	-	-

(1) Period 12-23-72 to 3-5-72.
(2) Isolated samples analyzed.
(3) Data presented in Table 4.

Laboratory Investigations

In order to better establish the critical design parameters required for the emulsion break at the Windsor oily waste treatment facilities, laboratory tests were undertaken to (1) identify the essential chemical reactions and (2) evaluate the treatment of oily wastewater from other Ford Manufacturing Plants.

The basic findings of the chemical reactions are as follows:

1. Extended exposure to acid at a pH of 2 to 3 is required for emulsion breaking. Sulphuric acid appears superior to hydrochloric acid. The efficiency of a typical oil emulsion break versus exposure time to acid is shown on Table 2.

2. Calcium chloride is essential to the emulsion break after acid digestion of the emulsifiers. Neutralization can be accomplished equally well with caustic or lime; however, lime neutralization would undoubtedly result in increased formation of precipitates and could result in sludge problems over an extended period of time.

3. Difficult emulsions can be broken with an extended acid exposure time or if after normal treatment is completed the treatment process is repeated. This latter approach, of course, increases the concentration of the dissolved solids.

4. The return of the floating precipitates from the tramp oil tank to the treatment tank acts to improve the oil emulsion break and insure that all oil, suspended solids, and newly-formed precipitates float rather than settle. Air mixing in the treatment tank is not essential for flotation.

5. The precipitates that are formed and recirculated are largely iron and calcium. Aluminum, phosphate and silica precipitates are also formed, but to a lesser extent.

TABLE 2
EFFECT OF ACID EXPOSURE TIME ON TREATMENT

Exposure Time of Wastewater To Acid In Hours	Oily Content In Treated Wastewater
0	4,432 mg/l
1	30 mg/l
2	22 mg/l
3 to 4-1/2	10 mg/l

Samples of oily wastewater were obtained from other Ford machining plants and jar tested utilizing the treatment process at Windsor. The results of this investigation are shown in Table 3.

TABLE 3
INVESTIGATION OF OTHER PLANT WASTEWATER
OIL IN MG/L

Location	Sample Untreated	Sample Treated	Comment
A	903	34	Transmission Plant
B	4,431	9	Transmission Plant
C	988	9	Engine Plant
D	5,500	27	Engine Plant
E	10,437	13.5	Stamping Plant

The investigations of other plant wastewater indicated that it was necessary to mix the "recycled precipitates" which have been formed at Windsor to improve the emulsion break and insure that all suspended material and precipitates floated to the surface. Although insufficient tests have been made to allow firm conclusions, it appears that the treatment process can be applied at certain other locations. There has been some inconclusive evidence that soluble draw compounds, which are often significant in stamping plant wastewater, may be unusually difficult to break.

SUSPENDED SOLIDS TREATMENT PROGRAM

Wastewater Sources

The major source of suspended solids results from Casting Plant operations. These are largely from the following operations:

1. Wet air scrubbers on cupola stacks consisting largely of condensed iron fume.
2. Wet air scrubbers over process equipment consisting largely of siliceous materials.
3. Molding equipment wash down of siliceous materials.
4. Slag removal from molten iron and subsequent quenching of slag in water.

An additional source of suspended solids which was associated with a wet bottom flyash removal system was eliminated at the Windsor powerhouse when a conversion was made from coal to gas/oil firing.

Wastewater Character

The wastewater from the Windsor Casting Plant was found to consist of 400 mg/l suspended inorganic solids in a waste stream and range from relatively large-sized slag particles to micron-sized iron fume from cupola wet scrubbers. The pH of the water is in the 4-7 pH range due to the cupola scrubbing of sulphur and fluoride ions from exhaust gases. Approximately 2 mg/l of iron is found dissolved in the water as a result of the above acidity.

Considerable investigation was undertaken in the design phase of the project to evaluate the most reliable and economic method of treatment. This included chemical flocculation/sedimentation in clarifiers and the use of deep bed filters. Because of the normal presence of dissolved iron in the water, laboratory investigation indicated that addition of lime would cause the iron to precipitate and act as a flocculant to coagulate the fine suspended solids. During periods when dissolved iron might not be in sufficient supply to cause flocculation, a polymer chemical would need to be available. Based on studies of both the installation and operating costs and the reliability of treatment, clarifiers were selected as the best treatment approach.

Suspended Solids Treatment Facilities

The Windsor Casting Plant wastewater is first directed to two slag pits equipped with dragout flights which provide a short settling time to allow heavy slag particles and gritty material to settle and be removed from the wastewater.

The above slag pits discharge into a 27 inch diameter gravity sewer which conveys the water to the clarifiers wet well where two 7,600 gpm constant speed mixed flow vertical pumps lift the wastewater to a flow splitter chamber. (All gallons are imperial gallons). At this point the pH is automatically measured and an appropriate quantity of lime slurry is added. The lime, which is stored in a 30 ton silo, is introduced into the flow splitter chamber to insure good mixing and allow the flocculated iron hydroxide precipitate to properly coagulate the suspended solids into dense particles which will rapidly settle.

Sedimentation is accomplished in two (2) 110 foot diameter clarifiers with 25'x 8' center flocculating zones. The clarifiers are designed for a total design flow of 5,600 gpm, maintaining a rise rate of below 450 gpd/sf. The clarifier detention time is 3.8 hours with a weir overflow rate of 2,500 gpd/lf. Solids are removed from the clarifiers and directed to one (1) of two (2) holding lagoons totaling 2.1 mg. Water decanted from the lagoons is returned to the wet well. When the #1 lagoon is full of sediment, #2 lagoon is placed in service and #1 lagoon is isolated and dredged of sediment. The clarifier system is shown in photograph 4 and on figure 3.

Serious consideration was initially given to installing vacuum filtration facilities to dewater the sludges. Recent experience with similar wastewater in the Ford Rouge complex indicates that design filter rates of 5#/hr/sf of dry weight solids can be expected to be quite adequate to achieve an excellent filter cake. The installation of such sludge dewatering facilities will relate directly to the future costs and attendant difficulties associated with disposal of relative wet inorganic sludges in land disposal sites.

As with startup of most pollution control equipment, difficulties have been encountered with maintaining continuous good control on the wastewater. This has largely related to pH control and lime feed equipment. In addition, wastewater sources containing suspended solids were found to be bypassing the treatment plant and require diversion from the storm sewer. Our Windsor personnel have identified these problems and are bringing them under control.

Table 4 outlines the overall operating efficiency of the suspended solids treatment facilities from January 1972 through March 1972. It is expected that removal efficiency will continue to improve. Facility costs are shown in Table 6.

TABLE 4
SUMMARY OF SUSPENDED SOLIDS TREATMENT

Item		Intake River Water	Influent To Clarifiers	Effluent From Clarifiers	Total Complex At River
Suspended Solids	mg/l				
Average		10	385	20	28
High Value		63	719	54	57
Low Value		1	174	4	6

FLUORIDE AND PHENOL CONTROL PROGRAM

Fluorides and phenols originate mainly from air scrubbing of exhaust gases of the cupolas. Calcium fluoride is used as a fluxing agent in the metallurgical process and evidently some of the residues are collected and become dissolved in the scrubber water. The Casting Plant water is treated with calcium hydroxide and the soluble fluoride ion above 15-20 mg/l is precipitated from the water.

Phenols originate from two sources within the Casting Plant. Coke which is utilized for a fuel in the cupolas emits a trace of phenol which is picked up in the wet scrubber air pollution systems. Phenolic binders are also employed to form cylinder sand core molds utilized in engine castings. At the time of the original survey, paints utilized in the machining Plants contained phenols. Traces of phenols also appear as a result of phenolic-based biocides used in the coolant systems.

Since trace quantities of phenols in large volumes of wastewater are not amenable to effective treatment, the control effort has been to minimize the phenol exposures to wastewater.

Coke often becomes surface-coated with phenolic residues at the coke oven manufacturing location as a result of the disposal of phenolic wastewater by quenching the incandescent coke. One measure to minimize the phenols at Casting Plants is to purchase coke which has not been quenched with phenolic bearing water.

Process equipment operating with phenolic materials for binders has been redesigned to collect dust with dry air pollution control equipment. Waste core sand which contains residues of phenol binders is handled dry to avoid leaching phenols into the water. Phenolic-based paints have been eliminated and use of phenolic biocides in coolants minimized. Data on fluorides and phenol control for a typical week in May 1972 is depicted in Table 5.

TABLE 5
FLUORIDE AND PHENOL CONTROL

Parameter		Intake River Water	Influent To Clarifiers	Effluent From Clarifiers	Total Complex At River
Fluorides	mg/l	(1)	40	18	4
Phenol	ug/l	(1)	160	80	5

(1) None detected.

INDUSTRIAL WASTE TREATMENT FACILITY COSTS

Program costs of the above mentioned facilities are outlined in Table 6 below.

TABLE 6
COSTS OF TREATMENT FACILITIES

Oily Wastes - Engine Plants	
Engine Plant #1 Segregation System	$ 157,000
Engine Plant #2 Segregation System	230,000
Oily Waste Treatment Facility	1,200,000
Chip Shelters	143,000
Engineering	70,000
Total	$ 1,800,000
Suspended Solids - Casting Plant	
Slag Pit Dragout System	$ 150,000
Sewers to Treatment Plant	55,000
Suspended Solids Waste Treatment	1,087,000
Engineering	108,000
Total	$1,400,000
Windsor Complex Total	$3,200,000

SUMMARY

The water pollution control program at the Windsor Complex required an approach which includes segregation of specific waste streams, change and control of processes and manufacturing techniques, and installation of treatment facilities to operate efficiently over a wide range of conditions.

The oily waste treatment facility is equipped with batch treatment tanks and employs an efficient treatment process which does not require sedimentation facilities. This has been a significant development in oily waste treatment at Ford, achieving excellent removal efficiencies of emulsified oil, suspended solids and phosphates. Minor volumes of floating precipitates are formed. Most of these precipitates are burned with the tramp oil; however, a portion are recycled to the treatment tanks to aid in the treatment process. From data developed to date, it would appear that this treatment process can be adapted to similar wastewater streams at other plants where conditions permit.

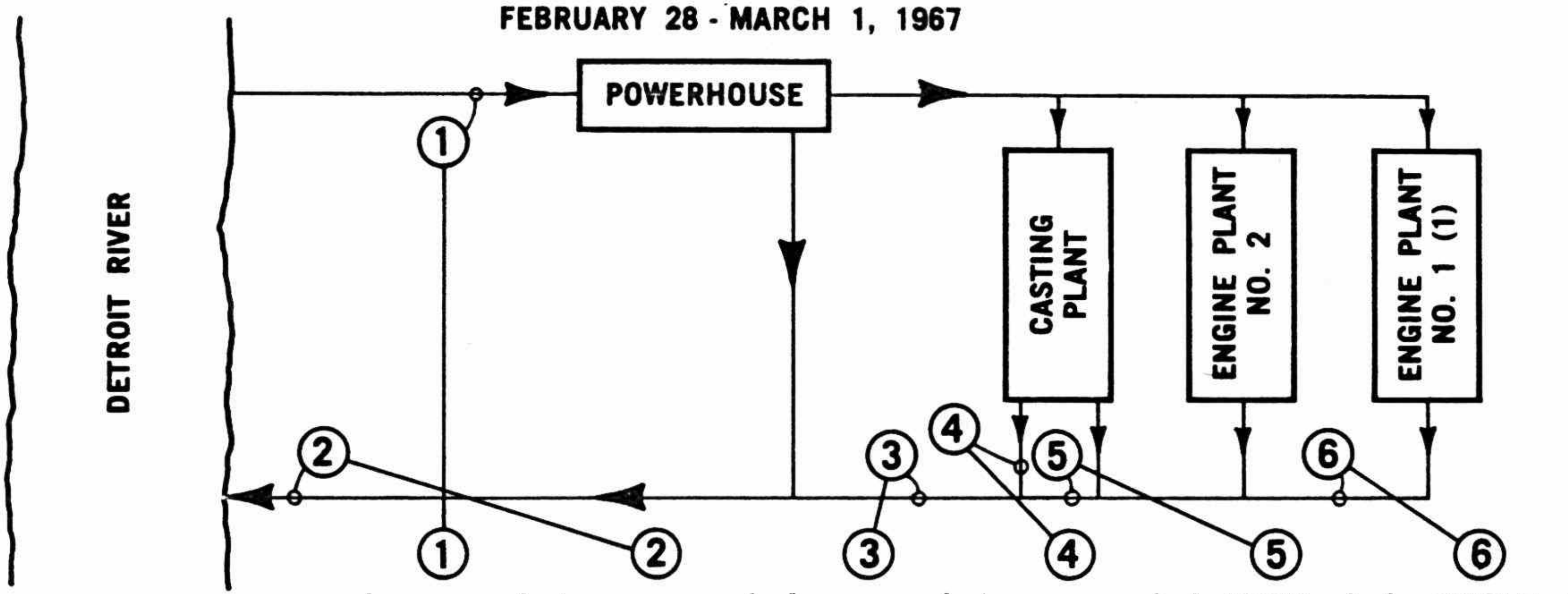
Suspended solids from the Windsor Casting Plant are removed by low rise rate conventional clarifiers utilizing lime to precipitate dissolved iron from the Casting Plant wastewater. Because the Casting Plant clarification system has been operational a relatively short time, a period of "debugging" and identification of wastewater streams bypassing treatment is still underway. Suspended solids are being reduced from an average of 400 mg/l of influent wastewater to an average of 10 to 20 mg/l in the effluent. Soluble fluorides are also reduced by precipitation with lime.

The wastewater treatment facilities at the Ford-Windsor Complex demonstrate that close cooperation and understanding between Government and industry can result in an improved environment while continued industrial activity contributes to a prosperous economy in the Province of Ontario.

PHOTOGRAPH I
AERIAL VIEW OF THE FORD-WINDSOR COMPLEX

PHOTOGRAPH 2
OIL DRAINAGE FROM METAL CHIPS AND TURNINGS IS CONTROLLED BY COVERING OUTSIDE WORKING AREAS

WINDSOR COMPLEX
24 HOUR INDUSTRIAL WASTE WATER SURVEY
FEBRUARY 28 - MARCH 1, 1967



SAMPLE		① INTAKE WATER	② DISCHARGE TOTAL	③ TOTAL MFG.	④ CASTINGS PLANT	⑤ TOTAL ENGINE PLANTS	⑥ SINGLE ENGINE PLANT (1)
ETHER SOLUBLE	mg/l	5	16	23	9	31	6
SUSPENDED SOLIDS	mg/l	3	114	234	361	102	48
PHENOL	ug/l	20	50	240	300	30	50
FLOW	igpm	31,000	31,000	8,500	5,100	3,000	750

(1) IN 1967 THE PLANT WAS A TRANSMISSION & CHASSIS PLANT NO. 6

FIGURE 1

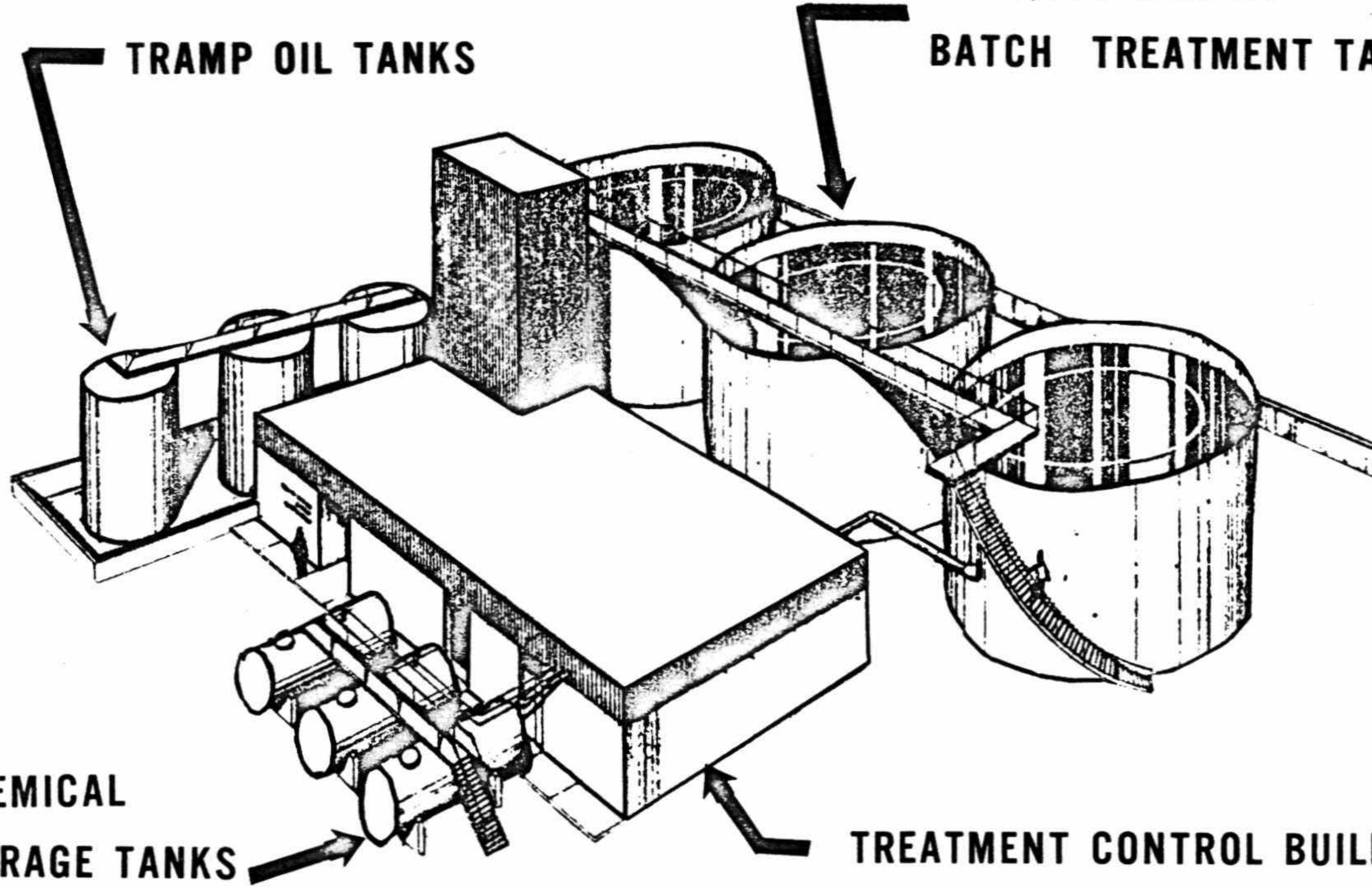


FIGURE 2

WINDSOR OILY WASTE TREATMENT FACILITY

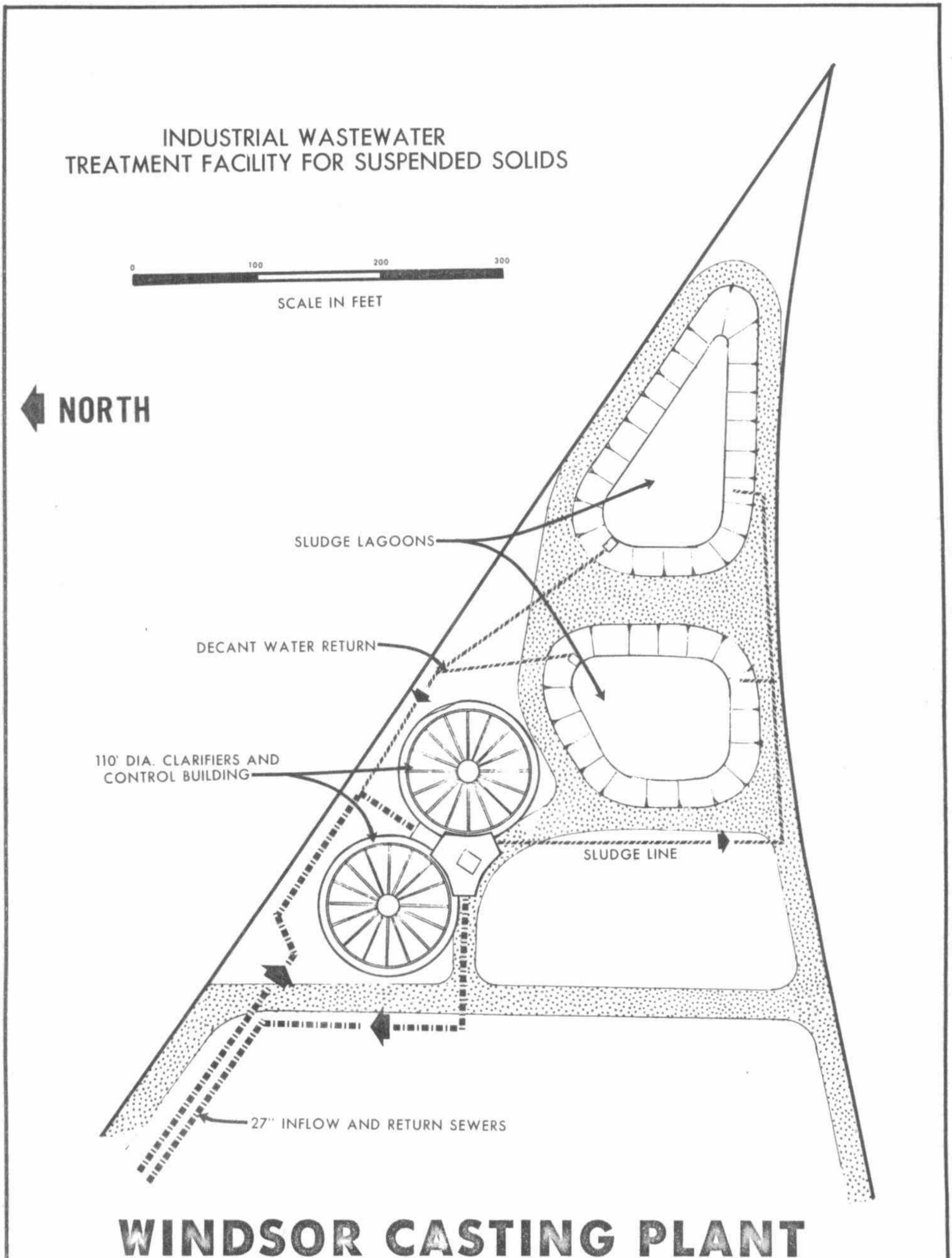

INDUSTRIAL WASTEWATER
TREATMENT FACILITY FOR SUSPENDED SOLIDS
0
100
200
300
SCALE IN FEET
NORTH
SLUDGE LAGOONS
DECANT WATER RETURN
110' DIA. CLARIFIERS AND
CONTROL BUILDING
SLUDGE LINE
27" INFLOW AND RETURN SEWERS
WINDSOR CASTING PLANT

FIGURE 3

F. Sweeney

DISPOSAL OF SLUDGES FROM AN EFFLUENT TREATMENT PLANT

BY

F. SWEENEY,
POLLUTION COORDINATOR

SHELL CANADA LIMITED,
OAKVILLE, ONTARIO.

FOREWORD

Although biological treatment is one of the most popular and effective processes used in waste water treatment systems, the disposal of the watery sludges which accumulate in such systems can present a trouble-some and/or costly problem for some installations.

This paper reviews the effluent treating facilities installed at Shell's Oakville refinery and gives an account of the on-site land disposal methods which are used to dispose of both oily and non-oily sludges. In the body of the paper, an attempt has been made to present the subject matter using terminology which will be familiar to the general reader or to field personnel in industry.

A better appreciation of some of the areas of special interest, i.e., the "bound" water problem, factors affecting biodegradation in soils and health hazards re-quires a degree of familiarity with the disciplines of sanitary engineering, soil science and microbiology. These areas of more specialized interest are discussed in greater detail in separate appendices where some of the more per-tinent technical concepts and vocabulary are introduced.


Queen Elizabeth Highway
--> To Toronto 25 mi.
Bronte Creek
Effluent Treating
Shell
BP Refinery
Burloak Drive
Storm Pond
Burlington
Oakville
park
Research Centre
Lake Ontario
Wharf

I INTRODUCTION

Oakville Refinery is located between the towns of Burlington and Oakville about equi-distant from Toronto and Hamilton. The area is now largely developed for suburban dwellings although other companies such as BP, Gulf, Texaco and the Ford Motor Company also have plants nearby. Locally, the population is very conscious of environmental quality and Burlington was the electoral district of Ontario's first Minister of The Environment.

Fortunately, the refinery is situated on a site which exceeds 600 acres. Most of the trees and wooded areas have been conserved in their original state and there are several fields which were formerly used for agricultural production. Some of these field areas are very suitable for the decomposition or biodegradation of organic residues.

The refinery had two reasons initially, for developing on-site disposal techniques:

The effluent treating plant has a number of ponds or basins which accumulate rather large volumes of watery residues. These ponds should be cleaned out once a year and although most of the ponds are in pairs, it is highly desirable to minimize the time that they are kept out of service. This objective can be best achieved by using on-site disposal facilities.

The second reason was associated with uncertainties regarding other disposal locations. Municipal dumps in general do not accept liquid wastes and our knowledge of the sites and methods used by local waste hauling contractors was extremely limited. Moreover, the stated policy of Ontario waste management authorities was to hold the producers of any waste, responsible for its ultimate disposal. A variety of other methods of disposal are available but most have drawbacks of one kind or another.

Dewatering, vacuum filtration, incineration, etc. are not only uneconomical for a relatively small refinery like Oakville but other installations have experienced disappointing results for other reasons, e.g., mechanical problems, irregularities in volume and composition of feedstocks, etc.

Pond bottoms have been disposed of on refinery premises since the first clean-out in 1965, and since 1967 other sludges including surplus biological sludge from the biotreater have also been applied to biodegradation areas.

Results have been very satisfactory. Not only can land disposal be the best solution from the overall ecological viewpoint, it can also be much lower in cost than any other acceptable method of disposal. The cost of disposing of these materials in some locations has been estimated at up to 50% of the total treatment plant costs.

The effluent treating plant consists of three API separators, two equalizing ponds, an air flotation unit, a biotreater/clarifier system which includes two tanks for aerobic digestion of surplus biological sludge and two final holding ponds. Ancillary equipment includes a deballasting tank, oil trap, storm pond and a fire water reserve pond.

A detailed description of this equipment was published in a 1964 paper.[1] Some changes have been made since this paper was prepared and some further alterations are either planned or in progress. An account of these changes, together with current analytical data, is given in Appendix 1.

Land disposal of organic residues can be a quite straight forward operation where large areas of fertile, well drained land are available. And the average home gardener will have a good appreciation of the principles and practices to be followed. However, when suitable land areas are limited, the operation becomes much more complex with the risk of a number of undesirable conditions developing.

The accumulation of residues and factors related to the choice and operation of disposal sites as well as potential hazards are described in the body of this report. A somewhat more detailed and technical treatment of areas of special interest such as the problem of separating water from sludge, the significance of nutrients together with other soil considerations and a further discussion of potential health hazards are presented in separate appendices.

II ACCUMULATION OF RESIDUES

a) Volume Of Residues

As shown in Figure I, the bottom of the API separators, the bottom of the slop oil sump, and to a lesser degree, the bottom of the air flotation unit accumulate oily residues which, in total, probably do not exceed 40 to 60 cubic yards per year. The sludge from the bottom of the API separators is normally pumped to one of two pits adjacent to the air flotation unit. These pits also receive oily froth skimmed from the air flotation unit as well as bottom sediments. After settling, the oil and water on the surface of the pit is gravitated back to

the API separators. The bottom oily residue which remains has not been analyzed for trace metals but it should be mentioned that the pH of the API separators which receive process wastes is normally in the range of 8.5 to 9.5. This level of pH is favourable for the precipitation of most metals and the metal content of this residue should be considered when choosing a method of disposal.[2)]

The storm pond and related basins e.g., storm API separator and oil trap, in past years have accumulated approximately 6 inches of sediment each year consisting mostly of clay and silt. Volume-wise this amounts to some 500 to 700 cubic yards. This rather large volume may be somewhat peculiar to Oakville because of the clay soil and the change in elevation of some 40 feet in the refinery area above the storm pond. The other pond bottoms accumulate sludge which is mostly biological in nature since biological activity is by no means confined to the biotreater.

The equalizing ponds accumulate up to 9 inches of watery sludge each year - equivalent to approximately 100,000 gallons. This sludge contains some silt and clay which may also have an admixture or coating of heavier oil fractions, but the majority of the volume of this sludge is a biological sludge, such as might be found on the bottom of a stagnant pond.

The biotreater/clarifier/digester system produces a net accumulation of some 6 to 8 thousand gallons of watery surplus sludge each week which contains only 2 to 4 percent of dry solids. The weight of ash of the dried solids varies from 20 to 40% consisting mostly of silica and alumina originating from the colloidal clay which is carried through to the biotreater following a rainstorm. Apart from some carryover of pin floc, very little suspended material is carried downstream of the biotreater/clarifier since the sticky biological floc acts as a very efficient filter for the removal of suspended solids.

It is expected that the final holding ponds will accumulate a volume of sludge equal to that found in the equalizing ponds. Overflow weirs were installed in these ponds in September of 1971, and there has not yet been an opportunity to assess the sludge accumulation over a one year period. Since the biological floc in the biotreater removes most other suspended solids, the sludge accumulation in the final holding ponds will be almost entirely biological. Part of this will result from the growth of algae which develops in the final holding ponds in summer. Algae do not develop in the equalizing ponds.

II b) The Bound Water Problem and Costs of Disposal

As a rule of thumb, each pound of organic matter that is removed from effluent water in a conventional activated sludge unit results in the production and accumulation of about one-half pound of new biological sludge - on a dry weight basis. But this is not the whole story. The surplus sludge which is removed from the clarifier is over 95% water and there is no simple mechanical means of separating most of this water. Dewatering of sludge is the problem which leads to high costs in many installations. A review of the mechanisms governing the production and reduction of biomass together with a discussion of the bound water problem is given in Appendix II.

A variety of methods are available for dewatering and processing biological sludge. Costs for some of these processes were published in a 1968 report by Burd[3]. Some additional information has been compiled by the consulting firm, Hydroscience Inc. of Westwood, New Jersey and the following table gives a more complete listing of estimates of approximate sludge handling costs. Costs shown are per equivalent dry ton.

TABLE 1

COMPARATIVE SLUDGE - HANDLING COSTS

PROCESS	$/Ton Capital	$/Ton Operating	$/Ton Total Cost
Thickening	1.0-2.4	2	1.5-5
Flotation	4-6	5-6*	6-15*
Anaerobic Digestion	10-25	2-4	11-30
Vacuum Filtration	5-13	8-32*	8-50*
Centrifugation	10-16	4-20*	14-35*
Sand Bed Drying	2-4	1-15	3-20
Lagooning	1-2	1-3	2-5
Incineration (W/Vacuum Filtration)	6-30	8-18	15-50
Wet Oxidation	28-30	20	48-55
Barging to sea	2-3	6-13	4-25

*Increases with chemical addition

Some costs relative to land disposal for the Metropolitan Chicago area which include costs of hauling are shown in Figure 5.

III DISPOSAL SITES AND METHODS OF DISPOSAL

a) Factors Affecting Choice of Sites and Methods

The choice of sites to be used as biodegradation areas as well as the methods employed are dictated by a number of requirements.

In Ontario, the operation of a waste disposal site or waste disposal system requires a certificate of approval from the Waste Management Branch of the Ministry of the Environment. Detailed information must be submitted with each application and prior approvals must be obtained from the local municipality and the Department of Health. Information required by the regulatory agencies includes type of soil and sub-soil, distances to nearest watercourse, source of potable water, dwelling, cemetery, and public road as well as information regarding the source and composition of the waste. Guidelines with respect to land characteristics, site management, site location and sludge application rates are available from the Ministry.

Perhaps the first question which occurs to anyone interested in land disposal of residues is how much land area is required? There is no simple answer to cover all circumstances but a number of guidelines are available:

At Oakville refinery it has been observed that pond bottoms should not be pumped onto a biodegradation area to a depth exceeding three to four inches at any one point simply because it takes too long for the wet, jelly-like sludge to dry out between rainfalls.

Eckenfelder[4)] reports loadings ranging from 100 dry tons/acre for average conditions to 300 tons/acre in areas of low rainfall.

In general, the thinner the layer that is applied, the sooner it will dry out and can be incorporated in the soil.

The type of soil and how it is managed are important factors to be considered as is the composition of the waste sludge, e.g., its content of sodium and other metals or constituents which are resistant to biodegradation. There are also a number of possible health hazards which cannot be ignored.

III a) cont'd...

At this refinery, residue disposal would be somewhat easier if the average clay content of the soil were not quite so high. Clay soils have some characteristics which are good up to a point, i.e., a high water-holding capacity, a high capacity to adsorb and immobilize metallic or other positively charged ions such as NH_4^+. Clay soils also have good ability to adsorb viruses. On the other hand, they are very susceptible to erosion if bare; their permeability is generally quite low; they must not be worked when too wet for fear of forming clods which could take years of freezing, thawing or cultivating before a granular structure is restored.

Soil areas used for biodegradation and/or crop production should be well above the water table. Some writers recommend a minimum distance of four to five feet.

The following is from a recent paper by Webber[5)] dealing with land disposal of treated sewage sludges:

"Desirable Soil Features

The kind of soil and the subsequent management of the soil and the crop cover largely determine the successfulness of the operation. In assessing the suitability of a soil the more important considerations are summarized:

1. A soil that is naturally well-drained; maintains an aerobic environment with less hazards of foul odours and soil clogging which are associated with anaerobic conditions; good drainage ensures the oxidation of organic matter and nitrogenous compounds in the organic and ammonium forms;

2. The preferred textures include fine sandy loams, loams and silt loams; gravels and coarse sands have an excessively high permeability and low exchange capacities; in heavy soils (some clay loams and clays) the permeability is too low and they are too slow in drying out;

3. The surface infiltration should be at least moderate, greater than 0.6 inches per hour as found in soils growing hay or pasture crops, the permeability coefficient of subsoils should be at least 0.2 inches per hour;

III a) cont'd...

4. A level to moderately undulating topography reduces the hazards of runoff and soil erosion; easier spreading of sludges with tankers;

5. The site should be accessible at all seasons; winter spreading would be confined to level or nearly level areas that are well removed from bodies of surface water and stream courses."

An important specific property of soils is their exchange capacity. This property can be determined quantitatively in a soils laboratory and is expressed as me/100g. -- Milliequivalents per 100 grams of soil.

The significance of the exchange capacities of different soils as well as other soil considerations such as the use of fertilizers is discussed further in Appendix III.

The foregoing may suggest why an "easy does it" approach is a good one as well as to indicate the difficulty of prescribing or making sweeping recommendations as to the land area required for disposal of sludges in terms of volume only.

In almost every province or state, there will be a soils laboratory with specialized facilities and personnel to analyse soils and assess their quality. Samples are best taken by experienced soils specialists who can then determine such things as the cation exchange capacity, the percent used by sodium saturation or base saturation, the permeability, the percent organic matter and levels of other available nutrients. Partly as a result of the large amount of work which will have already been done, these local specialists will be aware of nutritional or other deficiencies common to soils in a particular area. Given analytical data on the types of waste to be disposed of they can advise on suitability of areas for disposal purposes as well as methods, etc. With the greatly increased interest and emphasis on land disposal of sewage sludge and renovation of sewage plant effluent water, many soil scientists are currently assisting government regulatory agencies, etc., and they will be familiar with the practices which can be recommended for a given area.

III b) Disposal of Silt and Clay

The silt and clay which accumulates in the storm pond and related equipment does not quite fall into the category of a biodegradable residue. This sediment does not contain sufficient organic matter to warrant special treatment. To dispose of this material, a large area which has been termed the "silt pond" has been bulldozed along the upper side of the storm pond and surrounded with a dyke. Once a year, usually in the dry period in August, a front end loader is put into the storm pond to assist in "flowing" the slurry to the suction hose of a pump which is located in the lowest corner of the pond. The slurry is pumped into the silt pond and after a period of settling, the water is drained back into the storm pond. The following year, if necessary, before using the silt pond again, any mound of silt can be bulldozed to the opposite end of this silt pond.

c) Disposal of Equalizing Pond Bottoms or Oily Sludges

For the disposal of sludge which may contain some oil, an area of approximately 3 acres has been graded at a location which drains back to the effluent plant. This area is immediately across the road from the equalizing ponds and above the storm pond. The area is essentially level from side to side and has a gentle slope from top to bottom following the general slope of the terrain in this area. Adjacent to it, there is a large pile consisting mostly of topsoil which was saved from the time of refinery construction. Should it ever become necessary, material from this pile could be used to renew the bed.

Prior to use, this area is fertilized and treated with agricultural lime (crushed limestone). The limestone which has been used to date has been applied as a precaution against odours and may not be used in future. The area is then disc harrowed from side to side to create little furrows, and then divided up into a number of smaller beds by ploughing up small 8-12" temporary berms (dykes). When a slurry is pumped onto the high side of a bed, it is distributed automatically and fairly evenly over the bed without forming any deep pools of sludge (i.e., not greater than 3 to 4 inches), and thus not "suffocating" the soil micro-organisms over any large area or for a long period of time. A slightly deeper deposit could be applied to a more sandy soil or in a warmer climate.

III c) cont'd...

With a large enough bed or beds prepared in this manner, it is possible to pump over a year's accumulation of sludge from say one of the equalizing ponds in a day or two. A front end loader and/or a high pressure water hose can be used to help move the slurry to the pump suction.

Within about one week, the dark coloured, jelly-like sludge will begin to crack and shrink to about one-sixth of its original volume as it dries. When dry, the bed is disc harrowed to mix the residue with the soil and aerate it. The mixing also greatly increases the surface area of sludge particles for contact with both the soil organisms and other nutrients in the soil. The mixing and aerating speeds the odourless decomposition of the remaining biodegradable portions of the residue. The remaining residue is a good soil conditioner.

Before pumping out a pond, it is wise to check the weather forecast. Should a rainfall wash down appreciable amounts of sludge to the bottom of a bermed area, the material should be pumped back up over the beds before it begins to dry and cake. It will be difficult, if not impossible, to restore the sludge to a pumpable slurry once the shrinking and caking has begun. The thinner the initial deposit of sludge, the less likelihood there will be of a "washdown" problem.

Oily sludges from, say, the bottom of the API separators or the slop oil sump, have also been disposed of on the area which drains back to the effluent treating plant, and biodegradation has been quite successful. It is preferable to spread material of this kind as thinly as possible from a moving tank truck, and to disc or otherwise cultivate the surface more frequently.

Work reported todate[6) 7)], indicates that straight chain paraffins can be biodegraded relatively easily, the aromatics, the branched chain and the cycloparaffins with increasing difficulty as the molecular weight increases, but even the asphaltenes are slowly subject to microbial attack. Apparently oils, particularly those of higher viscosity have little tendency to migrate down into the soil but they do have a tendency to seal the soil and exclude air and thus inhibit biological activity until the soil is mixed and aerated.

III c) cont'd...

An alternative method of disposal has been used for the sludge which accumulates in the bottom of the pits adjacent to the air flotation unit. After taking one of the pits out of operation and decanting the surface oil and water, four to five parts of clean, sharp sand is dumped into the pit. The contents are mixed with a back-hoe and sand is added until a fairly stiff mix is obtained. The mix can then be spread as a top dressing on a secondary road. Alternatively, it might be spread along a fence line, or flare or other areas where it is desired to discourage growth of vegetation.

Oakville has very little in way of other oily sludges. Since the crude and other heavy oil tanks are all equipped with heaters and mixers, waxy residues have always been dissolved and reprocessed using a diluent when necessary. Before entry, crude tanks, etc. are given a final hot water wash to float any remaining light oil out the manways which are opened for this purpose. The small amount of remaining dry sediment presents no disposal problem. When using temperatures of 125 to 150 deg. F to avoid damaging the floating roof seals on a crude tank, melting the waxy deposit can be rather slow. Progress can be checked by feeling the difference in temperature between the liquid and solid wax with one's hand where the tank mixer or mixers have least effect.

d) Disposal of Surplus Digested Biological Sludge

This material is sprayed year 'round on selected sites on the refinery premises, using the refinery vacuum truck. Grassed fields or lawns which are essentially level can be used, provided proper care is taken to ensure that the material cannot find its way into a public watercourse. Usually, this means spraying on areas which drain back to the effluent treating plant.

During wet weather, areas amounting to some six acres are available which have a series of gravel roads or strips. These strips were laid down during the refinery construction period to create dry, accessible areas for the storage of piping and other materials of construction. These areas also drain back to the effluent plant. An important step which

III d) cont'd...

makes on-site land disposal of surplus biological sludge feasible without an odour problem is the prestabilization of the waste sludge in aerobic digesters. Many municipal plants use anaerobic digesters--the sludge from which can sometimes be quite smelly by comparison.

Loehr,[8] in a very informative paper "Aerobic Digestion: Factors Affecting Design" discusses results obtained by himself and others using aerobic digestion and makes the following comment:

> "Aerobic digestion, however, is a process which, if operated correctly, can produce a minimum amount of biodegradable solids. The residue from this process is a stable sludge with low oxygen demand, good settling characteristics and no offensive odour."

e) Disposal of Final Holding Pond Bottoms and Long Term Disposal

For long term disposal, another area comprising some forty acres was designated as a waste disposal site when making application for a certificate of approval from the Waste Management Branch of the Ontario Department of the Environment. To date, approximately seven acres of this area has been bermed and used for disposing of sludge from the final holding ponds. This area is accessible by, and surrounded with an all-weather road. Sludge from pond bottoms is pumped through 4 inch irrigation-type aluminum pipe. While this area was being graded, it was found that the type of soil changed near the lower end of the area from clay to a deep overburden of fine sandy loam. This is a most desirable type of soil in this location, since it does not have the shortcomings of a predominantly clay soil. Moreover, following a rainfall there is no need to decant or drain off surface water from the bermed area. The good drainage characteristics in this area relieves concern over the possibility of pathogenic, i.e., disease causing organisms getting into a public watercourse.

IV HEALTH HAZARDS

Much of the recent knowledge concerning health hazards associated with sludge or effluent disposal results from studies of municipal sewage sludge and effluent disposal.

Hazards stem from a variety of possible sources: microbes, toxic metals or other toxic chemicals.

Many pathogenic organisms survive exposure to septic tanks or secondary treatment. Sludge digestion as normally carried out will greatly reduce but will not eliminate all disease causing organisms and chlorination at the levels normally applied will not destroy many pathogens, e.g., viruses in particular.

At Oakville refinery domestic waste is first treated in septic tanks which discharge into the oily water sewer. Although domestic waste is only a very small fraction of the total waste in the oily water sewer which also contains phenols and has a fairly high pH, it cannot be assumed that there is no risk associated with land disposal of sludges. Septic tanks, incidentally, should be cleaned out every 3 to 5 years to get rid of accumulated solids which reduce their capacity and efficiency or in some cases may cause plugging of soil tiles.

Oakville refinery, in co-operation with the Ontario Water Resources Commission and the Department of Health, have been monitoring the bacteriological quality of their effluent for more than a year. Based on results obtained to date, the effluent is judged to be a good quality effluent - sufficiently good in fact that resumption of chlorine injection which was suspended over a year ago has not been called for.

Studies to date have involved the coliform group which belong to the family Enterobacteriaceae[9]. Further work is planned to study the occurrence of members of the family Pseudomonadaceae. This family is widely distributed in nature and some of its members figure prominently in the biodegradation of phenols and oils. Some of the members of this family are pathogenic to man and Pseudomonas aeruginosa, for example, has been implicated in numerous infections of man, such as: septicemias, endocarditis, meningitis, infections of the middle and external ear, as well as many other localized infections which occur less frequently.[12]

In view of recent work identifying Pseudomonas stutzeri[11] with the biodegration of oils in soil, the following discussion from a paper by Reid [12] is of interest:

> "A search of the literature showed that there appears to be some doubt as to the species of Pseudomonas that are pathogenic to man --- Gilardi however, stated that, Ps. aeruginosa and Ps. pseudomallei are generally recognized as the only pseudomanads pathogenic to man, but Ps. stutzeri and Ps. maltophilia have been incriminated as human pathogens."

IV cont'd...

Krone[13] discusses the die-away rates of micro-organisms in the soil, the filtration/straining mechanisms in different soils as well as the sorption of viruses near the soil surface. He recommends that a soil containing clay should be used for irrigation with treated sewage.

The die-away rates or survival times of many disease causing micro-organisms as determined by a number of investigators have been tabulated by Dunlop[14]. A few of these are as follows:

Salmonella typhi (typhoid fever) - up to 70 days in soil, up to 3 weeks in lettuce, 3 to 5 days in Lake water;

Endamoeba histolytica cysts (Amebic dysentry) - 8 days in soil, 18-42 hours in tomatoes, 18 hours in lettuce;

Enteroviruses - 12 days in soil, Tubercle bacilli - 6 months in soil, 3 months in sewage.

The foregoing examples represent the results reported by some researchers under certain conditions. Different results could be expected under other conditions. Survival times of pathogenic bacteria and viruses are known to be very dependent on temperature as well as other factors. In general, the bacteria and viruses survive longer at lower temperatures.[33]

In spite of the seemingly long survival times of some of these micro-organisms, public health authorities in general permit land disposal of sewage sludge provided that certain precautions are observed.

Coerver[15] tabulated the results of a questionnaire sent to each state health department. While there are some variations in regulations in different states, the use of untreated sewage for irrigation is generally prohibited. States approve the use of treated sewage for irrigation except in the more hazardous situations involving vegetables eaten raw, public access lawns, and dairy pastures. In the last case the concern is presumably due to the risk of udder infection rather than to the likelihood of the survival of pathogens through a cow's four stomachs.

There are a number of factors which reduce the hazards of bacterial infection, e.g., few pathogenic bacteria can form spores as a defense under unfavourable conditions. It is believed that all are killed by the ultra-violet rays of the sun. Standards of sewage and water treatment are such that bacterial infection from public water supplies has become very rare, etc.

IV cont'd...

On the other hand, personnel working with sewage sludge must exercise careful personal hygiene.

The risk of infection by pathogenic micro-organisms is not the only health hazard. Careless dumping of inadequately digested sludge can encourage disease carrying insects. Some sludges may contain concentrations of metals that can be toxic to plants, animals and thus indirectly to humans.

Most aerobically digested sludges will contain high levels of nitrates and where large volumes are involved, this factor alone may be the determining factor which will limit the volume of sludge that can be applied to a given land area. Excess nitrates in water or food are hazardous to both animals and man. The nitrate can be converted into nitrite which is readily absorbed into the blood and reacts with the blood to reduce its oxygen carrying capacity. This type of poisoning is known as methemoglobinemia and it can be fatal - particularly in infants.

Planting and harvesting of crops reduces the risk of an excessive amount of nitrates getting into water supplies. Webber[5] discusses the nitrate question as well as the effect of metals in soils and gives the following as guidelines for rates of applications:

(1) a 100 bushel corn crop will remove 150 to 200 pounds of nitrogen per acre and a hay-pasture mixture would remove 300 to 500 pounds per acre.

(2) additions of organic materials enhance the productivity of most soils and

(3) if soil pH is maintained at or above 7.0, the hazards of heavy metal contamination are reduced.

V DISCUSSION

Surplus sludge can be regarded as a resource, which, if returned to the land in a proper manner, can be beneficial to the soil. It is especially interesting that these methods are not only the most suitable means of recycling wastes from the ecological viewpoint, but, at the same time, they can be the lowest cost acceptable methods yet devised.

As far as the operator in the field is concerned, the general principles and practices to be followed are virtually identical to those understood by the average home gardener or farmer. The main concepts can be reviewed or illustrated briefly in the following fashion:

V cont'd...

He knows that a flower pot should have a hole in the bottom to ensure proper drainage and that if the flower pot is placed in a pan, the plant can be watered by adding water to the pan. The water will find its way up to the roots by capillary action and carry dissolved nutrients with it. He may not fully appreciate that the film of water which surrounds the soil particles is also important to the micro-organisms in the soil but he knows that the addition of peat moss, for example, improves the water-holding capacity of the soil and prevents it from drying out too quickly. In addition, maintaining a good soil condition or tilth allows air to penetrate into the soil. He is also acquainted with the use of fertilizers.

The average householder will have observed that if he cuts his grass regularly, the short clippings that fall and come in contact with the soil, somehow seem to disappear as they undergo biodegradation. On the other hand, if the grass is left to grow too long before cutting, so that piles of cuttings are left supported above the soil, he knows they will not disappear within a reasonable period of time and that he should rake them up and dispose of them in some other way such as digging them into the soil or adding them to a compost heap together with some fertilizer. He will also have observed that droppings from birds or a stray dog also seem to disappear within a week or so, especially in wet, warm weather. Should he cut his finger he knows that it is probably wise to discontinue gardening activities for fear of infecting the wound and for similar considerations he would wash his hands before eating.

One difference between the activities of the home gardener or farmer and the operator of a sludge disposal area which could be a source for some confusion is the difference in visual results. The gardener or farmer has the incentive to do what he thinks is right because he derives pleasure from seeing things grow or he anticipates a profitable crop. The operator of a biodegradation area, on the other hand, merely sees something disappearing and it may be difficult to convince him that he is growing a wonderful "crop" of essentially invisible, though very necessary, micro-organisms. But this is indeed the case.

To obtain successful results, one must always bear in mind that it is the macro-and micro-organisms in the soil that carry out the biodegradation processes, and man's activities in way of preparing the soil or applying the sludge are designed to accommodate the needs of the desirable types of organisms in the soil. Covering the soil with too deep a "shield" of sludge on poorly drained soil of low permeability will not work; neither will the hole-in-the-ground approach. Either of these approaches can encourage the growth of putrefactive bacteria or encourage insects

V cont'd...

which spread disease, etc.

The desirable organisms require oxygen, and while certain bacteria can obtain their oxygen by breaking down chemicals containing oxygen, they usually produce smelly by-products in the process. Other soil organisms which are important decomposers of organic waste - the fungi and the actinomycetes are essentially strict aerobes, i.e., they must have their oxygen readily available.

In the foregoing, it has been implied that the operation of a biodegradation area is as easy as growing grass. It can be. But some soils, some climates and some wastes are not as suitable as others. There are problems associated with the maintenance of a good lawn. And soils can become less productive or even sterile.

Reference has also been made to a number of potential hazards. Where industrial wastes are concerned, one should have as complete and detailed analyses as possible for both wastes and soils. An analytical programme for monitoring the soil condition may be necessary. Although much is known, there is still much to be learned, particularly in the area of long term effects. The general guideline therefore, is to proceed with caution.

Where the availability of suitable land areas is limited, the determination of such things as maximum application rates for sludge, maximum biodegradation rates together with the optimum use of fertilizers becomes much more of a complex science than a home-grown art. A local soils scientist should be consulted on such matters. The fruitfulness of such consultation can depend in part, on the ability of both parties to speak in common terms. The problem of communications between different disciplines is frequently referred to - particularly in the sphere of environmental control. Some background reading is often necessary and it is hoped that this paper together with the list of references attached will be found helpful to those interested in these subjects.

APPENDIX 1

CURRENT OPERATING DATA

OAKVILLE REFINERY - EFFLUENT TREATMENT PLANT

Since publication of a descriptive report in 1964, [1] a few changes have been made and some further changes are projected. An outline of these changes is as follows:

The refinery throughput has been increased from 32,000 to 42,000 B/D.

Phenol-rich, sour water from the cat. cracker overhead accumulator, is now preferentially routed to the crude desalter, rather than directly to the sour water stripper. Phenols are largely absorbed in the crude fraction boiling up to 600°F and this fraction is routed to the hydrotreater, where most of the phenols are destroyed.

An early warning pH alarm system has been installed in the oily water sewer in the process area, and an improved sensing device has been installed for pH control at the outlet of the API separators.

Originally, effluent could be pumped from the outlet of the equalizing ponds by taking suction from either the top (downward opening sluice gate) or the bottom. A curtain wall has been installed to permit taking suction from mid-level of the equalizing ponds.

A windscreen made of wooden slats has been installed around the top of the air flotation unit.

The 7.5 hp. motors for the Vortair mixers in the biotreater have been re-wound to permit drawing a higher amperage. Initially, and particularly when operating the biotreater in series operation, these motors were prone to tripping out on overload when the throughput was increased. The biotreater is now operated in parallel and the outlet weirs have been raised so that the Vortair mixers are more deeply submerged to provide increased oxygen transfer.

The injection of chlorine dioxide was discontinued and more recently, injection of chlorine has been suspended as well.

The final holding ponds were originally operated in blocked-out operation. Overflow weirs have been installed and these ponds are now operated full and in parallel. This mode of operation has resulted in a substantial reduction in BOD_5 and suspended solids in the final effluent.

Installation of additional equalizing pond capacity has been included in the budget for 1972. Pipework associated with new pond capacity will permit isolation and dilution of any slugs of high strength wastes.

Other plans are being developed to increase automation of the plant - particularly with respect to oil skimming and improved control of levels throughout the plant. The feasibility of storing surplus biological sludge in the final holding ponds during winter months will also be investigated.

Current analytical data are shown in the following table:

TABLE 2 ANALYTICAL DATA

	API Separator Outlet ppm	Final Effluent ppm	Final Effluent Range ppm
Flow usgpm		530	380-900
Ammonia (as N)		100	69-140
Calcium (as Ca CO_3)		181	170-190
Chlorides (as Cl)		290	264-322
Chromate (Cr^{+6})		0.02	
Copper		0.02	
Cyanides (ppb)		60	20-100
Fluoride		0.23	
Iron		0.28	
Lead		0.04	
Magnesium		11.7	
Mercaptans		nil	
Phosphates (total as P_2O_5)		0.9	0.6-1.3
Sulphate ($SO_4^{=}$)		709	632-790
Sulphides (as S)		0.3	0.0-0.8
Zinc		0.07	
Oil (Ether extractible)	16	3.0	1-15
Phenols (ppb)	8720	6.7	0-30
BOD (5 day)	122	21	4-48
COD	452	241	112-506
pH	9.0	7.3	6.1-7.7
Turbidity (JTU)		25	15-35
Suspended Solids (filterable)	36	12.4	4-103
Dissolved Solids		1592	1494-1761
Fish Toxicity (96 hr TL_{50}) % vol.		93	

APPENDIX II

PRODUCTION AND REDUCTION OF BIOMASS

The following is a brief introductory account of the mechanisms governing the production and reduction of biomass in an activated sludge unit:

Shortly after the recycle sludge has been mixed with incoming feed in the biotreater, a population explosion takes place among the bacterial forms, with an attendant high consumption of oxygen and evolution of CO_2. This activity can be simply illustrated with the following equation: Cells + Organic Matter + O_2 + NH_3 $\longrightarrow$ New Cells + CO_2 + H_2O.

The reactions are aided by organic catalysts or enzymes which are secreted by the bacterial cells. After a time, the bacterial forms do not multiply as rapidly, but continue to respire and utilize organic matter for energy and cell maintenance. This is known as the endogenous phase and during endogenous respiration, the bacteria will also metabolize carbohydrates, lipids (fats) and proteins which they have manufactured and stored in their cells. This activity can be illustrated with the following simplified equation: Cells + O_2 $\longrightarrow$ CO_2 + H_2O + NH_3.

A more accurate definition of endogenous respiration is that bacteria when suspended in buffer solutions without substrate (the material acted upon by an enzyme) will utilize the oxidizable material already accumulated inside the cells. The decreased rate of growth which ensues in an activated sludge unit or digester is possibly due more to the local accumulation of toxic end products than to the exhaustion of the food supply. Just as in wine making for example, the cells of the yeast *Saccharomyces ellipsoideus* die off once the concentration of alcohol reaches a certain level even though there may still be a good supply of sugar left in the system.

In any event, as the availability of the food supply or concentration of toxic substances changes, many of the bacteria die and are lysed (much of the contents of their cells are dissolved by intra-cellular enzymes and becomes available as food for living cells). Meanwhile simple bodied, one-celled animals, the protozoa as well as other not-so-simple-bodied animals, the metazoa[(6)] forage on the plant-like bacteria and in the process help to produce a clearer effluent.

The population dynamics of the different forms of life are presented in a very readable form by McKinney[17] who, incidently, says, "The concept that the bacteria eat one another in a cannibalistic manner is absurd." Procedures for measuring the production and reduction of biomass and relating it to BOD_5 or COD reduction can be found in Eckenfelder.[4]

More recently, work done by others, e.g., Henry and Jones at the University of Toronto[18] has shown that the yield of microbial cells from a particular substrate is not as constant as it was widely believed to be. This work shows how temperature, detention time and substrate concentration can all affect the cell yield in an aerobic reactor.

When surplus sludge is transferred from the clarifier of a conventional activated sludge unit to an aerobic digester, a number of things occur. The dry weight of the biomass can be reduced by approximately 50%, depending on such things as detention time, temperature and the availability of nutrients. Most disease-causing bacteria will die[19] and the readily biodegradable (putrescible) fraction of the organic matter will be converted into carbon dioxide and water. Unfortunately, much of the water which went into the manufacture of new cells or became physically trapped in the biological floc remains as a colloidal gel and there is no simple mechanical means of separating most of this water.

The average composition of protoplasm, the living matter contained in all cells, is 80% water and much of it exists as a thixotropic colloid. When the cell dies, the colloidal material shifts irreversibly from the sol to the gel state (e.g., as in the case of rigor mortis). The difficulty of separating this water might be likened to that of separating the water from the white of an egg.

The external slime layer of bacterial cells has long been thought of as an amorphous material consisting mainly of polysaccharides. Recent work using the electron microscope[32] has shown this material to consist of structured fibrils forming membranes on which it is believed many of the enzyme reactions occur. These structures or "mats" would also suggest physico-chemical reasons for the "bound" water problem.

There are a number of means of reducing the water content: down to say 90-95% by digestion, settling, decanting, elutriation, or to 85-90% by thickening, to 70-80% by vacuum filtration or centrifugation, etc. No doubt, manufacturers of some equipment can show somewhat further reductions under ideal conditions. The literature on the subject is rather large[19] [20] [21] and unfortunately, very often, so is the cost.

Eckenfelder[4] reports that sewage sludge stored in a lagoon can be dewatered from 95% moisture to 55-60% moisture in a two to three year period.

Odour problems are frequently associated with lagoon operations, particularly in spring. When this route is chosen, good predigestion, lagoon design and pH control are advisable. Under anaerobic conditions, sulphates for example, can be reduced with the evolution of H_2S.

If the incineration route is chosen, dewatering using a thickener or other means will reduce the cost of auxilliary fuel. On the other hand, Burd[3] reports that digestion of sludge prior to incineration is undesirable, as it reduces the thermal value of the sludge by about 50%.

Loehr[8] reports on the improved drainability of sludges with detention time in a digester, and Eckenfelder[4] reports that where sludge is applied to sand drying beds for subsequent removal in a "liftable" state, alum treatment can reduce the sludge drying time by 50%.

Further discussions on different sludge dewatering and disposal methods can be found in a number of references. Much useful information can be found in the WPCF manuals of practice #8, 20. It is understood that WPCF manual of practice #2, "Utilization of Wastewater Sludge", will be reissued this year.

APPENDIX III

BIODEGRADATION IN SOILS

Contrary to the opinion of many persons, the soil is not a dead, inert material. Actually, it is full of life - for a thimbleful of soil contains billions of living micro-organisms. While the micro-organisms found in activated sludge will, for all practical purposes, also be found in the soil, the spectrum of living things in the soil is much broader. Compounds that are not broken down in a biotreater or digester may be broken down in the soil where there will be many varieties of organisms that are powerful decomposers of organic matter. Some forms, e.g., the actinomycetes (ray fungi or thread bacteria), which have characteristics intermediate between those of bacteria and fungi are also the producers of many of the modern-day antibiotics, which destroy disease-causing bacteria. All these forms of life require certain essential nutrients.

The nutrient requirements for plants include carbon, oxygen, hydrogen, nitrogen, phosphorous, calcium, magnesium and sulphur with trace amounts of boron, copper, iron, manganese, molybdenum and zinc. Plants may also contain sodium, iodine, chlorine, calcium, silicon and aluminum, but this group is not classed as essential for plant nutrition.[22]

For rapid, odourless decomposition of organic matter, it is desirable to encourage the heterotrophic aerobic bacteria, i.e., those that require organic compounds for their supply of carbon and energy as well as free dissolved oxygen. A soil that will yield a vigorous plant growth will also support a large population of the desirable bacteria, fungi and other micro and macro-organisms, and is unlikely to be deficient in the minor elements.

Common nutritional deficiencies are nitrogen, phosphorous and potassium, and these are the principal elements supplied in commercial fertilizers. Some soils do not require all three, e.g., some soils in Western Canada and the United States are rich in potash whilst the blue-grass area of Kentucky is rich in phosphates.

McKinney[17], discussing the composition of bacteria and their nutrient requirements, states that,

> "The composition of bacteria is 80% water and 20% dry matter. The dry matter is 90% organic and 10% inorganic. The organic fraction gives an empirical formulation of $C_5H_7O_2N$. The inorganic fraction averages 50% P_2O_5, 6% K_2O, 11% Na_2O, 8% MgO, 9% CaO, 15% So_3 and 1% Fe_2O_3.

> The bacteria must derive all the basic elements for protoplasm from the liquid environment. If the liquid environment is deficient in one or two elements, the bacteria will develop only in proportion to the chemical deficiency."

When oily sludges, comprised mostly of hydrocarbons, are applied to the soil-especially if applied in a thick layer it is almost assured that N at least, probably P and possibly K, will be in short supply in the micro-environment of the soil. These deficiencies can be overcome by adding N, P and K in the form of commercial fertilizers and mixing the sludge thoroughly and frequently with the soil. On the other hand, if the soil has been used previously for the biodegradation of surplus biological sludge, there will be less need for the P and K since these elements had to be present to manufacture the biological sludge in the first place. Some of the N will also become available for reuse if the soil contains clay or has an appreciable content of residual organic matter, but N is most likely to be deficient because of volatilization losses and leeching since all nitrates are soluble.

McKinney also gives the empirical formula for fungi as $C_{10}H_{17}O_6N$ and comments:

> "Comparing the formulation of fungi and bacteria shows the immediate difference in nitrogen content. The fungi form normal protoplasm with one-half the nitrogen required by the bacteria. Thus, it is not surprising that fungi predominate over bacteria in nitrogen-deficient environments. A nitrogen-deficient environment for the bacteria is not so deficient for the fungi."

The foregoing suggests that rapid decomposition of oily wastes will usually require a supplementary source of N and P - the same nutrients that must be added to an activated sludge unit when there is an insufficient supply in the influent.

This need has been born out experimentally both in water and soil.

Bridie and Bos[23)] in a study of biodegradation of oils in water, concluded that the degradation rate for crude oil depends almost entirely on the availability of the bacterial nutrients, nitrogen and phosphorous, without which biodegradation will take many months instead of days.

Schwendinger[6] showed how biodegradation of oils in soil could be increased by the addition of fertilizer solution containing increasing levels of N and P. He also showed that for soils heavily contaminated with oil, biodegradation rates could be increased by seeding with acclimated bacteria, although for lower levels of contamination the seeding made little difference.

A study of Schwendinger's report suggests that a good time to apply additional fertilizer might be three to four weeks after application of an oily sludge, i.e., after initial drying and mixing of the sludge residue with the soil. As in lawn feeding, two or more light applications of fertilizer may give better results than one heavy application.

Oil will biodegrade slowly without the addition of fertilizer, especially if added to a fertile, well-drained soil in small amounts. The soil will receive inputs of nitrogen from precipitation, and from nitrifying bacteria and N subsequently becomes available through the decomposition of organic matter. Furthermore, in the dynamic soil system other elements are being moved around by soil organisms, as well as by physico-chemical processes. However, the decomposition rate will be slower without fertilizer and the fungi which require less nitrogen than the bacteria will probably increase and the bacteria which degrade most hydrocarbons at a more rapid rate will probably decrease. The actinomycetes which include the genera Mycobacteria Nocardia and Streptomyces, among others, have also been identified as significant decomposers of hydrocarbons or other organic matter. The actinomycetes favour a plentiful supply of oxygen and can continue working in relatively dry soil. Hence, one might expect to find more of these micro-organisms in a well-drained, well-aerated soil.

In the case of applying surplus digested biological sludge to the soil, there is probably no need for supplementary fertilizer and if sprayed thinly on a grassed area there is no need for mixing with the soil, at least Oakville Refinery have not found this to be necessary over a period of four years.

Exchange Capacity Of Soil

The nucleus or micelle of a colloidal clay particle, (Greek words "kolla" meaning glue, and "oid" meaning like) can be visualized as a diagram of an atom with a lot of negative charges around it. A soil exhibits a physical-chemical property of adsorbing positively charged ions to the negatively charged clay micelles, as well as to the soil organic matter. The exchange capacity increases with increases in clay and organic matter contents. Ions on the exchange complex are subject to partial displacement by a mass influx of another ion such as sodium. A surplus of sodium can result in the deflocculation

of colloids; the soil structure will break down and the soil will become impermeable and useless. On the other hand, such conditions can be prevented or corrected by the use of chemical treatment, e.g., calcium sulphate (gypsum) or powdered sulphur. Calcium sulphate supplies the calcium to displace the Na from the exchange complex. The Na^+ and the $SO_4^=$ then form a salt which is leached out. Likewise H_2SO_4 supplies H ions which displace the Na and then the Na_2So_4 salt is formed as above. In the second case, the sulphur is first oxidized to So_3 by microbial action and then combines with water to form sulphuric acid.

Natural precipitation will also contribute to a re-alignment between the ions on the exchange complex.[5] Different clays have different exchange capacities. Montmorrillonite, the type generally found in Ontario, has approximately five times the exchange capacity of kaolinite, the type prevalent in the State of Georgia. Illite is a third type of clay which has an exchange capacity that is intermediate in value. Stabilized organic matter (humus) can greatly increase the exchange capacity, depending on pH. Difficulties can be expected when more than 10 to 15 percent of the exchange capacity becomes saturated with sodium.

As an example of one way of disposing of sludge, the following procedures have been employed by the Campbell Soup Company for a plant designed to process 30,000 head of poultry on an eight-hour shift.[24] Surplus biological sludge is accumulated during the winter months in a storage pond and is disposed of on adjacent land during the spring/summer/fall months. The disposal area is prepared before use as follows:

1. Plough and disc.
2. Apply one ton/acre crushed limestone.
3. Disc.
4. Apply 1000 lbs./acre 13-13-13 fertilizer.
5. Add 50 lbs./acre seed mixture made up of:

   20% perennial rye
   30% meadow fescue
   50% canary reed

It is understood that the sludge is sprayed over the grassed area.

Covering the soil with a grass mixture improves the infiltration rate and reduces the risk of run-off.

In large scale application of sewage effluents to soil at Flushing Meadows, near Phoenix, Arizona, Bouwer[25] also reports that grassed areas have a better infiltration rate than either bare soil or soil covered with gravel. The sewage effluent is purified as it passes through the soil and is subsequently re-

covered and used for recreational purposes. Fifty million gallons of water a day from a secondary treatment plant are recovered in this way, at a cost of about $5.00 per acre-foot, and it is estimated that the cost of renovating the water to a similar quality using in-plant processes would be $50.00 per acre-foot or ten times as much.

Many other cities are using land disposal for a variety of reasons. Most communities in Ontario, with the exception of the two largest cities - Toronto and London - use land disposal for digested sewage sludge. Chicago has been turning to this method on a very large scale.

Other communities use land disposal systems of sewage plant effluent with irrigation and utilization of nutrients for crops as the main objectives, e.g., Tucson (Arizona), Melbourne (Australia), Paris, Berlin, etc.

In other localities the main purpose of applying sewage water to soil is for renovation and reuse, e.g., Whittier Narrows near Los Angeles and Santee near San Diego. In Western Holland, Rhine river water is purified by filtering it through sand dunes. Other such systems are planned for Tel Aviv and Phoenix.[25]

It is by no means improbable that similar systems for treating and reuse of water may be the best route for certain refinery effluents in lieu of in-plant treating steps.

With respect to the use of landfill techniques for the disposal of other wastes, Farvolden and Hughes[26] stated:

> "Our conclusions are that the landfill method can be used safely for the disposal of wastes, almost anywhere, provided that proper design and operational techniques are followed to suit the conditions at the site."

APPENDIX IV

HEALTH HAZARDS

The best known of the bacteria in sewage are the coliform group. These are classified in the family Enterobacteriaceae.[9] These organisms are used as indicators of fecal pollution because they are found in the feces of all warm blooded animals but they are not all pathogenic. Krone[13] discusses the subject as follows:

"The common practice is to examine water for coliform organisms, and if present, to consider the water potentially hazardous. Raw sewage contains on the order of 10^6 coliform organisms per millilitre.

The incidence of pathogens in sewage depends on the incidence of diseased persons contributing, and to the shedding rate of the particular organisms. A typhoid carrier for example, may shed 200 million *S. typhosa* daily, and an amebic dysentry carrier may shed 10 million *E. histolytica* per day."

Approximately half the mass of human feces consists of surplus bacterial biomass grown in the intestine and it has been reported[27] that human excreta contains from 100 to 400 billion coliform bacteria per capita per day, and the per capita production of bacteria of all kinds is possibly 1000 times greater.

Bacteriologists and public health authorities have long recognized the limitations of the standard MPN (most probable number) coliform test and other more specific tests are either in general use or are proposed.

One such test is for *Pseudomonas aeruginosa*. Various researchers[12] believe that the standard coliform tests should be supplemented with a pseudomonas test in a routine water examination; one of the reasons being that bacteria causing eye, ear, nose and throat infections are more important than indicator bacteria in swimming waters. Apparently *Ps. aeruginosa* is rarely if ever, found in the surface water in the absence of human or animal contamination and it is a rather sensitive indicator.

One drawback to implementing such testing on a general scale is that there appears to be some doubt as to the species of pseudomonads that are pathogenic to man. The Pseudomonads are a large family, ubiquitous in nature. Reid[12] in his study of the media and procedures used by

various authors notes that while two members of this family are generally recognized as the only pseudomonads pathogenic to man, Gilardi[29] states that two others have been incriminated as human pathogens. One of these is Ps. stutzeri, the species reported by Dotson, Dean, Kenner and Cooke of the FWQA[11] in their study of bacteria found in the oily sludge at both Shell Houston and Marathon Oil refineries. This species was the one which showed the most rapid growth during the biodegradation of oil. Until testing procedures, etc. are clarified, it would be prudent to assume that Ps. stutzeri is the species reported and that it is a pathogen.

As mentioned earlier, the bacteriological laboratories of the Ontario Water Resources Commission have been monitoring the non-chlorinated effluent at Oakville Refinery. Testing for pseudomonads has not yet commenced pending further refinements in testing techniques.

Chlorination of final effluent, if not required, is simply the addition of another pollutant. Reports from three states indicate that chlorine combines with ammonia and phenols present in effluent from secondary treatment to form chloramines and chlorophenols which are toxic to game fish. Studies are to be undertaken this year in Wyoming and Michigan to compare ozone with chlorine compounds.[28]

The survival of viruses is still a matter of some concern to public health officials. For many years it was almost impossible to study viruses because they could not be reproduced outside their hosts. The science of virology was completely revolutionized following the Nobel Prize winning discovery of Enders and his co-workers who demonstrated that the virus of poliomyelitis could be propagated outside an animal host by using tissue cultures.

Approximately 100 new enteric viruses have been discovered largely through the use of tissue cultures. For the most part, they are shed by children under 15 years of age.[33]

The virus or viruses causing infectious hepatitis is thought to be particularly resistant to the treatment processes in sewage and water works.[5] Much remains to be learned in this area.

Other Toxic Substances

A bioassay on Oakville's non-chlorinated effluent yielded quite good results, i.e., using Speckled trout, the 96-hour TL_{50} value was 93 percent by volume of the effluent.

Where traces of toxic metals might be suspected, a likely place to look is in the surplus biological sludge. The biomass should have considerable ability to concentrate or magnify certain pollutants. The protozoa can consume enormous numbers of bacteria. Alexander[37] has indicated that 40,000 bacteria are consumed in the growth of one protazoa while the Encyclopedia Britannica (1962) states that one Paramecium may ingest as many as 5,000,000 bacteria in 24 hours.

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FIGURE I OAKVILLE EFFLUENT PLANT

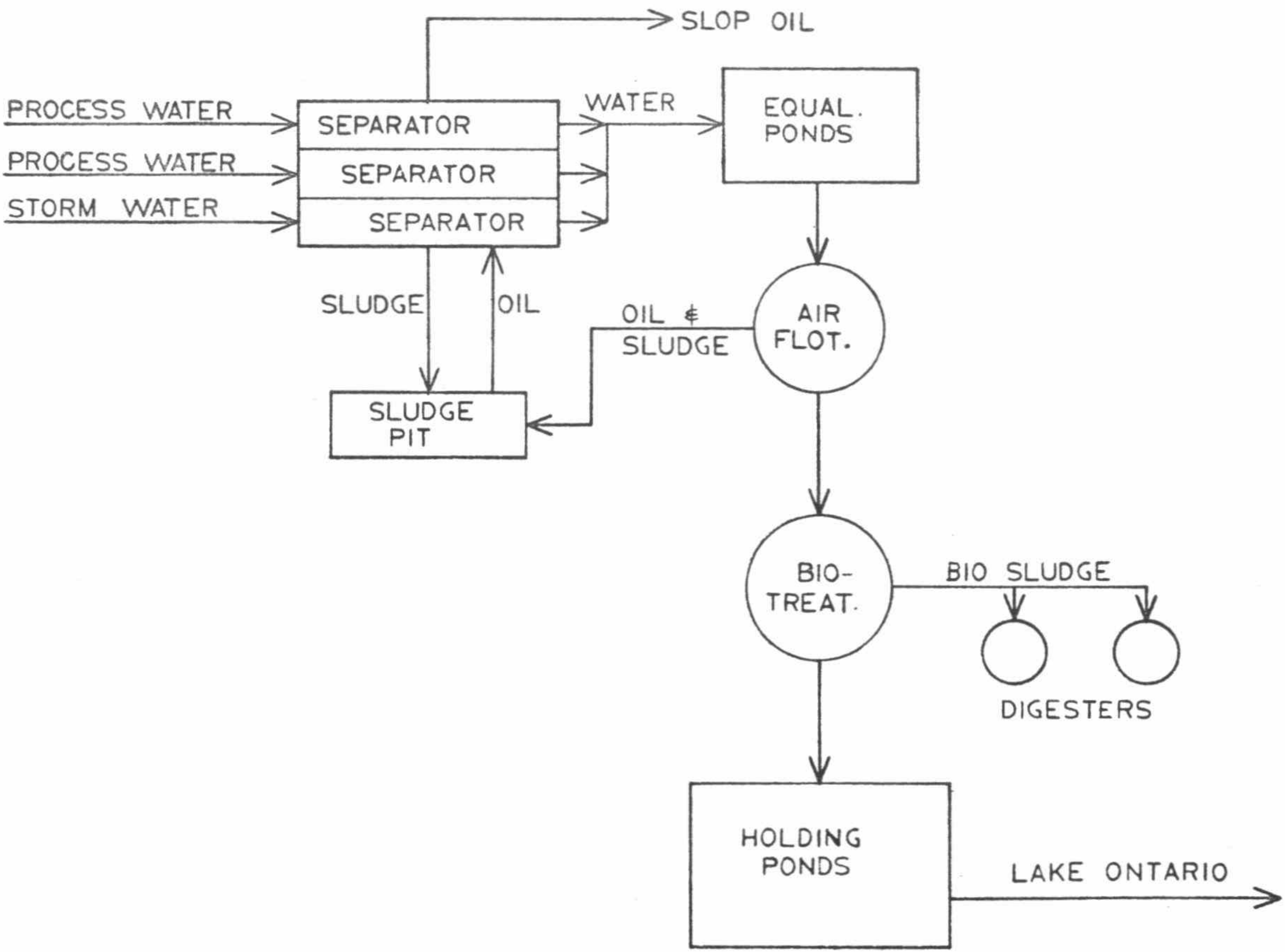


FIGURE 2

PERFORMANCE DATA

		IN	OUT
BOD	PPM	120	20
COD	PPM	450	240
S. SOLIDS	PPM	—	12
PHENOL	PPB	8,500	7
OIL	PPM	—	5

FIGURE 3

SLUDGE VOLUMES

SEPARATORS / AIR FLOTATION	50 CU. YD./YR.
EQ. PONDS	100,000 GAL./YR.
HOLD. PONDS	100,000 GAL./YR.
BIOTREATER	1,000 GAL./DAY

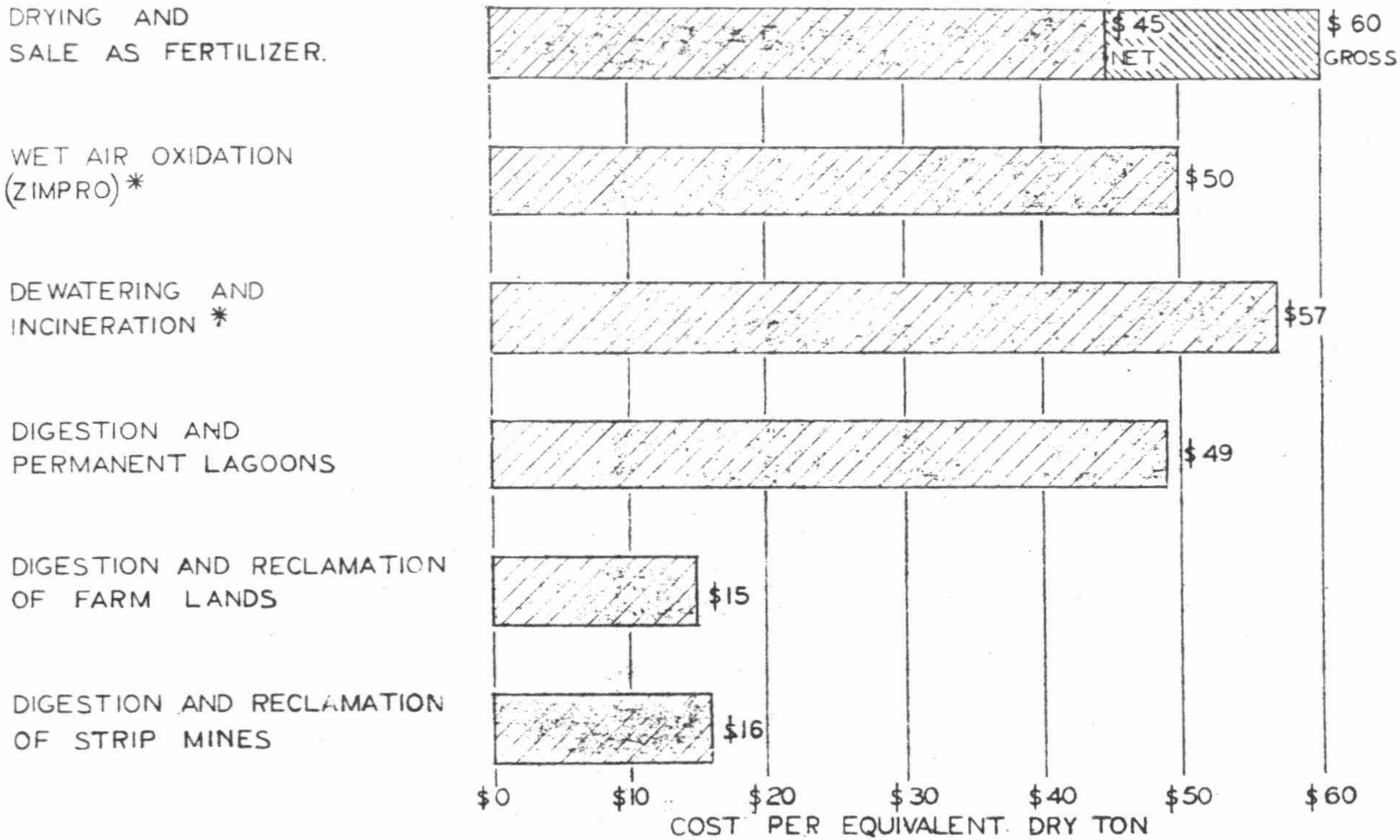
FIGURE 4.

COMPARATIVE SLUDGE HANDLING COSTS

PROCESS.	$/TON CAPITAL	$/TON OPERATING	$/TON TOTAL COST
THICKENING	1. - 2.40	2.	1.50 - 5.
FLOTATION	4. - 6.	5. - 6.*	6. - 15.*
ANAEROBIC DIGESTION	10. - 25.	2. - 4.	11. - 30.
VACUUM FILTRATION	5. - 13	8. - 32.*	8. - 50.*
CENTRIFUGATION	10. - 16.	4. - 20.*	14. - 35.*
SAND-BED DRYING	2. - 4.	1. - 15.	3 - 20
LAGOONING	1. - 2.	1. - 3.	2. - 5
INCINERATION (W/VAC. FILT.)	6. - 30.	8. - 18.	15. - 50.
WET OXIDATION	28. - 30.	20.	48. - 55.
BARGING TO SEA]	2. - 3.	6. - 13.	4. - 25.

* INCREASES WITH CHEMICAL ADDITION

FIGURE 5.



*PRECEDED BY HIGH RATE DIGESTION.

COSTS OF DISPOSAL METHODS FOR ACTIVATED SLUDGE.

FROM: WPCF JOURNAL #5 PART 1. MAY 1968.

FIGURE 6

BED DESIGN / OPERATION

SOIL PERMEABILITY

DRAINAGE

GRADE & DISC HARROW

LIMESTONE & FERTILIZER

SLUDGE DEPTH 4" MAX.

REPEAT DISC HARROWING

FIGURE 7

FACTORS DETERMINING BED LIFE

SLUDGE LOADING

METAL CONTENT OF SLUDGE

ION EXCHANGE CAPACITY OF SOIL

SOIL TREATMENT

CROPPING

FIGURE 8

HEALTH PRECAUTIONS

AEROBICALLY DIGEST THE SLUDGE

GOOD HYGIENE BY OPERATORS

AVOID RUN OFF

DO NOT USE ON FRESH PRODUCE

WASTE DISPOSAL SYSTEMS
FROM A GROUNDWATER HYDROLOGY
AND POLLUTION POINT OF VIEW

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INTRODUCTION

Rapid increases in population and industrialization are resulting in an expanding quantity and complexity of liquid and solid, industrial, municipal and agricultural wastes. In addition, accelerating urbanization is leading toward a progressive localization of waste generation. It is evident, therefore, that methods of waste management which do not result in the pollution of surface or ground water will be imperative, and in the case of liquid wastes the emphasis will have to be placed upon renovation and reuse rather than disposal.

Disposal and treatment of solid and liquid wastes on the land are gaining wider acceptance. Numerous methods for dealing with the many types of waste are available: solids, depending on the source, may be land-filled or spread; while liquids are handled by systems employing infiltration basins, surface flooding and spray irrigation. Although these operations have the potential to seriously contaminate both ground and surface water, this paper emphasizes the implications of land disposal in terms of ground-water hydrology and pollution. Spray

irrigation is cited as a specific example, and some of the criteria which are essential for a proper evaluation of the pollution potential of proposed operations are also discussed.

SIGNIFICANCE OF GROUND WATER

In order to appreciate the implications of ground-water pollution it is essential to understand the role of ground water in the hydrologic cycle, and to be familiar with the basic principles of ground-water hydrology.

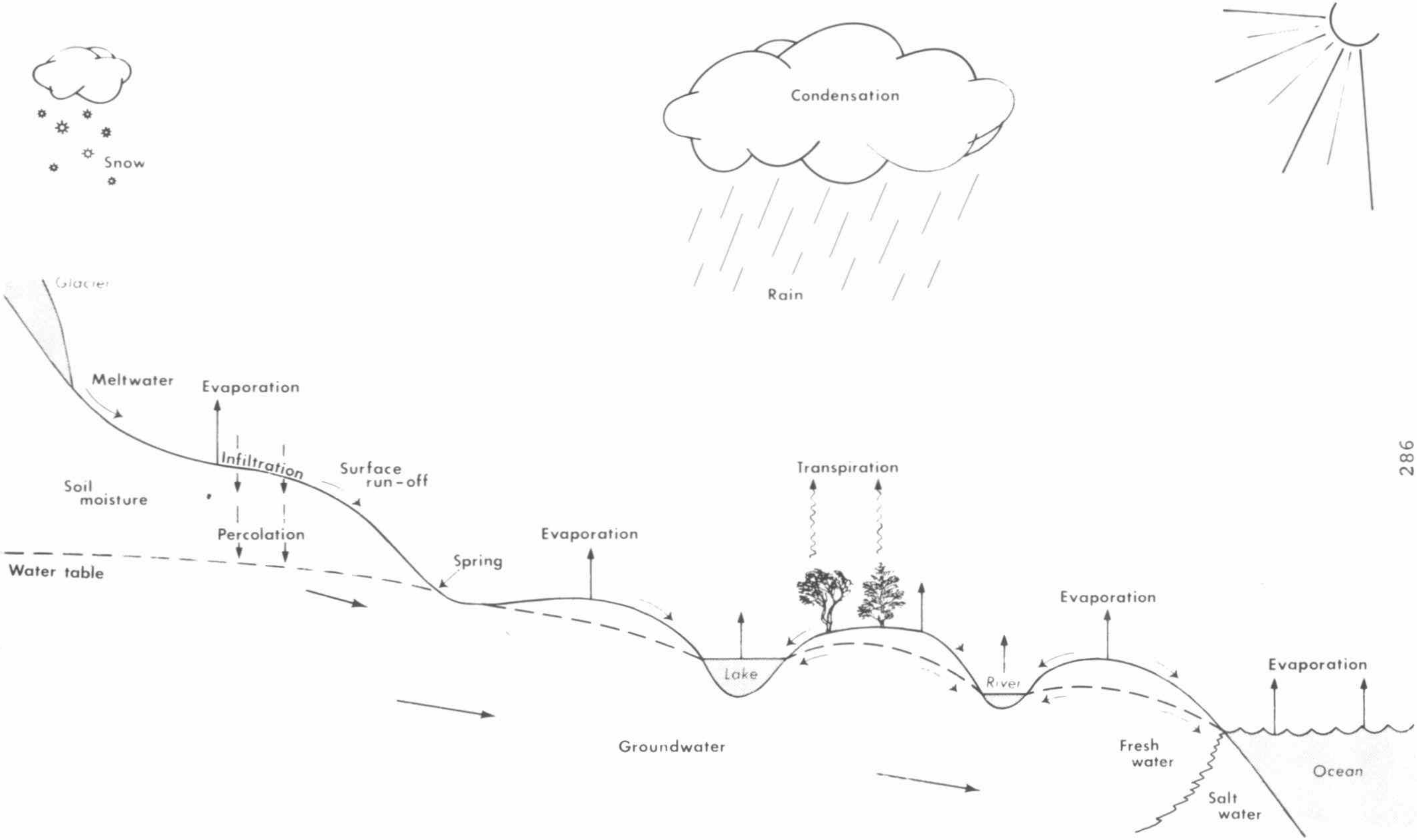
Hydrologic Cycle

The hydrologic cycle (Figure 1) includes the processes by which water on earth moves. Solar radiation is the source of energy which maintains the cycle. The sun evaporates water from water, land and plant surfaces into the atmosphere. The water vapour eventually condenses and returns to the earth's surface as rain or snow. Some of this water may be immediately evaporated again, and the rest either runs off into streams, lakes or the ocean, or infiltrates the soil surface. Of the portion which infiltrates, some is transpired by plants, while the remainder passes downward to become part of the ground-water reservoir. Ground water, acting under the influence of gravity, flows down-gradient through the materials of the earth and eventually discharges on the surface through springs, or into lakes, streams or the ocean.

Many reservoirs of varying sizes may be defined in the hydrologic cycle. The ocean, by far the largest reservoir, contains about 97 per cent of all the earth's water, (Wolman 1962). The remaining 3 per cent is distributed in a number of reservoirs as shown in Figure 2. It should be noted that ground water comprises about 25 per cent of the total fresh water reservoir, while surface and atmospheric water constitute less than 0.5 per cent. The largest portion is contained in glaciers and polar ice.

Ground Water Hydrology

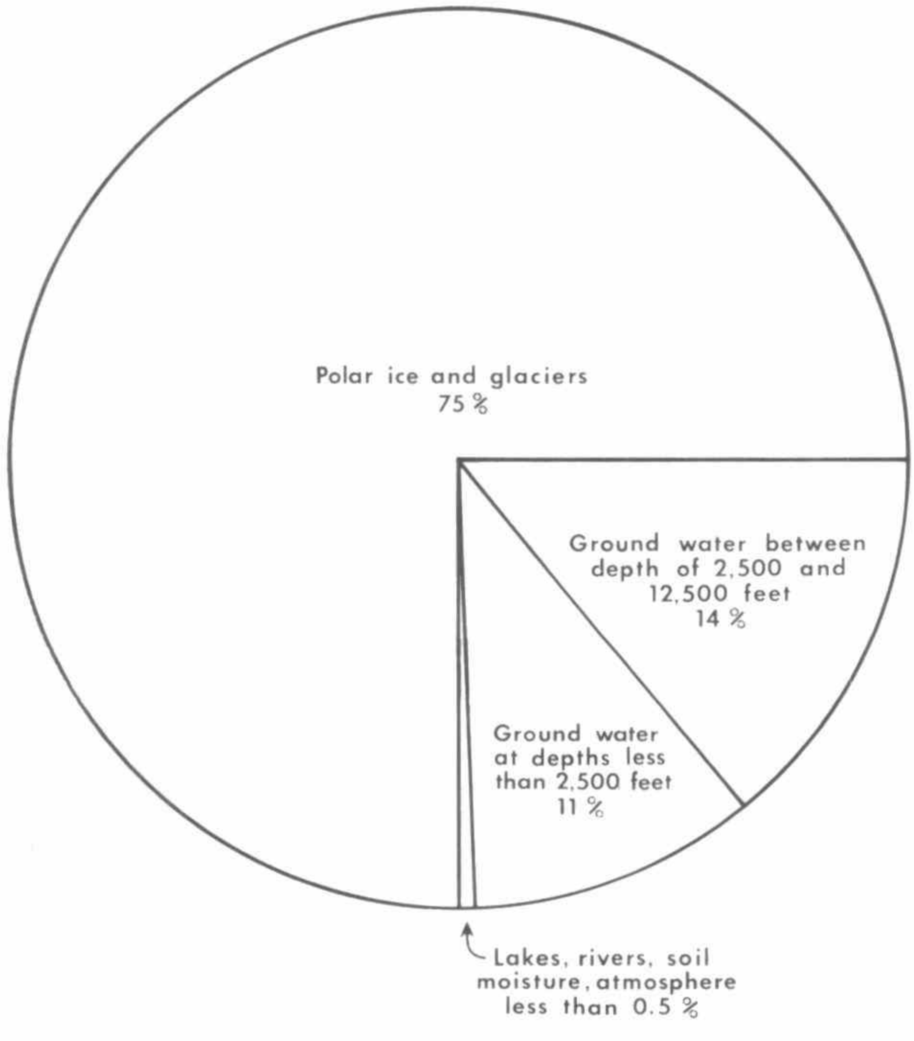
The subsurface occurrence of water is divisible into two zones: an upper zone of aeration in which the interstices are only partially filled with water, and a lower zone of saturation in which the interstices are completely filled with water. Ground water in the zone of saturation flows under the influence of gravity from regions of higher fluid potential to areas of lower potential. The rate of movement depends upon the gradient of the potential and the permeability of the material



Snow
Condensation
Rain
Glacier
Meltwater
Evaporation
Infiltration
Surface run-off
Soil moisture
Percolation
Water table
Spring
Evaporation
Transpiration
Lake
River
Evaporation
Evaporation
Groundwater
Fresh water
Salt water
Ocean

Figure 1.

Figure 2.



From: Wolman, Abel, Water resources; a report to the Committee on Natural Resources of the National Academy of Sciences. National Research Council Pub. 1,000 - B, Washington, D.C., 1962.

through which it is flowing. Permeability is a measure of the ease with which water passes through a rock or unconsolidated sediment, and is usually quite variable, both vertically and horizontally. It is dependent upon the pore size in unconsolidated sediments, while in rocks permeability is largely a function of the size, continuity and density of fractures.

Relatively permeable water-bearing units are called aquifers. Two types of aquifers are usually defined: unconfined aquifers in which the upper surface of the zone of saturation is at atmospheric pressure, and confined aquifers which are contained by an overlying relatively impermeable stratum and have fluid pressures in excess of one atmosphere. Figure 3 illustrates these concepts. The direction of ground-water flow is shown by the arrows in Figure 3. In unconfined aquifers the ground-water flow direction is down-gradient in terms of the slope of the water-table surface, and in confined aquifers ground-water flows down-gradient with respect to the slope of the piezometric surface. The elevation of the water-table or piezometric surface is a measure of the fluid potential at each location. Usually, water-table and piezometric surfaces are subdued replicas of ground surface topography. Therefore, shallow ground waters generally move downslope in terms of surface topography.

GROUND WATER POLLUTION

Significance of Ground Water

It is apparent from Figure 2 that ground water is a significant reservoir of fresh water. However, only a small fraction of ground water is contained in aquifers which are capable of yielding water at rates sufficient to supply domestic, municipal or industrial demands. In the United States, about 20 per cent of all the fresh water used is derived from ground-water sources and more than 95 per cent of the rural population is dependent upon ground water. Although ground water is not the largest source of fresh water it is certainly a significant component.

For some uses, ground water has properties that make it a more desirable supply than surface water. For example, ground waters are generally free of pathogenic organisms, are nearly constant in temperature, are less likely to contain suspended solids, and supplies are less seriously affected by droughts than surface waters. Therefore, ground water is an important source of high quality fresh water which must be protected from pollution.

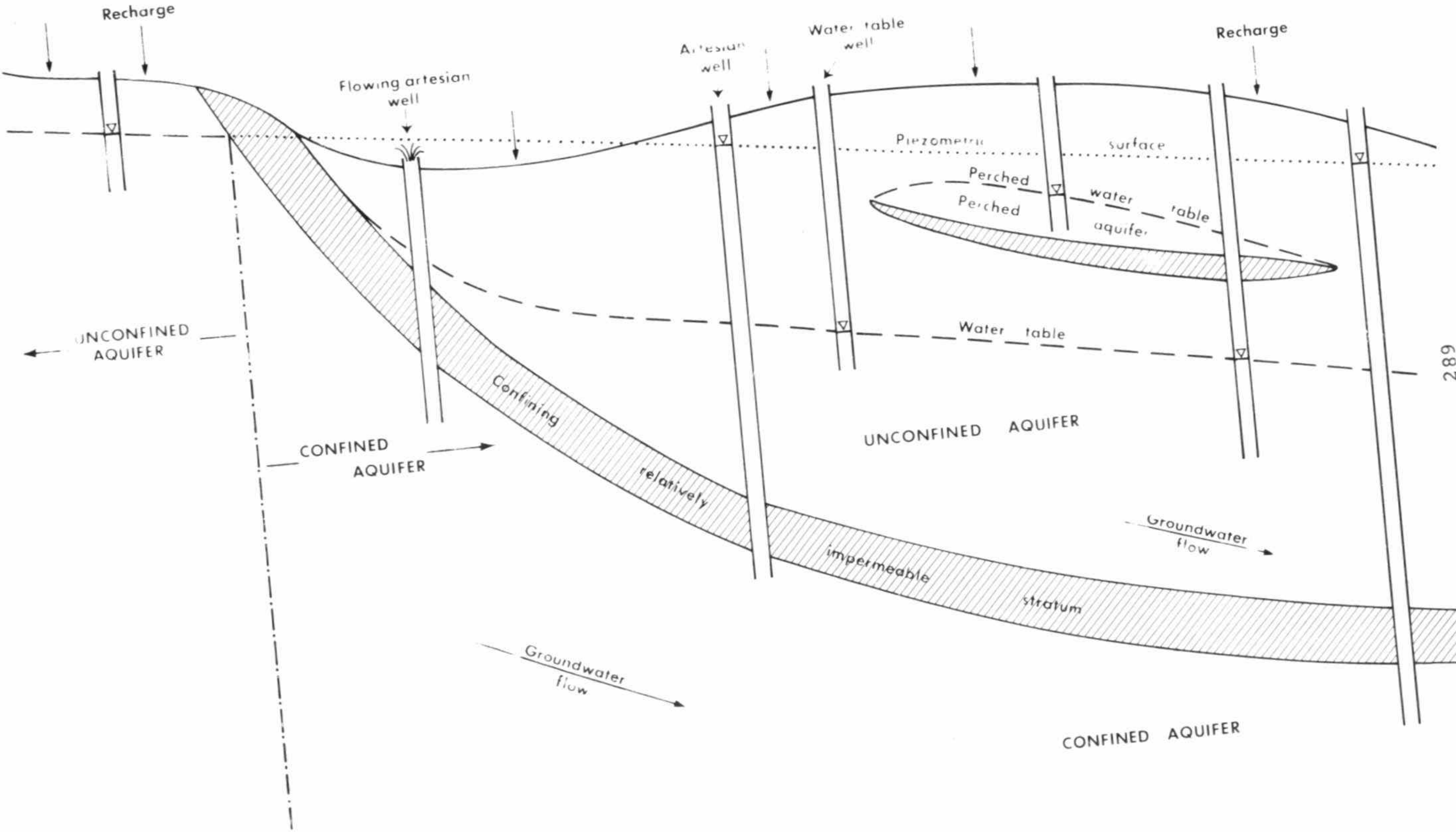

Recharge
Recharge
Flowing artesian well
well
Water table well
Recharge
Piezometric surface
Perched water table
Perched aquifer
UNCONFINED AQUIFER
Water table
UNCONFINED AQUIFER
Confining relatively impermeable stratum
CONFINED AQUIFER
Groundwater flow
Groundwater flow
CONFINED AQUIFER

Figure 3.

Natural Ground Water Quality

Prior to describing the types of pollutants which may affect ground water, it is necessary to briefly discuss natural ground-water quality and the factors which affect it. The chemical composition of ground water depends largely on the mineralogy of the materials through which it flows. In general, the concentration of dissolved salts increases as water passes through a ground-water system toward discharge areas. Unless minerals such as sulphides or soluble evaporite salts are present, most shallow ground waters are of suitable quality for domestic, municipal and industrial uses.

Types of Pollutants

The types of substances which may contaminate surface waters will not necessarily pollute ground water. Physical, chemical and biologic processes that may occur in the subsurface environment can modify or eliminate some contaminants. That is, to be an effective ground-water pollutant a component must be mobile within the entire soil/sediment complex through which the ground waters pass.

Suspended solids are usually removed by filtration during percolation and do not generally cause serious problems in ground waters. Soluble components are not removed by filtration, but may be significantly reduced in concentration by adsorption, ion exchange or the formation of insoluble precipitates. All solids that are in contact with liquids are covered with a thin layer of adsorbed molecules or ions. The total quantity of material adsorbed is a function of the surface area and mineralogy of the solid and the type of ions or molecules involved. Adsorbed ions may be replaced by other ions which are introduced to the geologic environment. This replacement process, ion exchange, generally obeys the law of mass action. In most natural exchange media there is an excess of negative charge in certain areas of the crystal lattices, and thus, a predominance of cations are adsorbed. Divalent cations such as calcium and magnesium are generally more strongly adsorbed than monovalent ions such as sodium. Common anions such as bicarbonate, sulphate and chloride are only weakly adsorbed.

A number of potential contaminants may be removed through incorporation into inorganic precipitates. The mixing of a waste with ground water, or the reaction between an effluent and the sediments can result in supersaturation with respect to many solid phases. These solids, which are commonly carbonates, hydroxides or oxides, do not continue to move with the ground water.

Biologic assimilation and degradation are particularly significant in soil horizons. Vegetation efficiently absorbs nutrients from soil water, and biochemical oxidation or reduction may be effective in decomposing organic contaminants and reducing the oxygen demand of infiltrating waters. However, within the subsurface environment the process of aeration is restricted, and anaerobic conditions may develop if a high oxygen demand remains in the waters which percolate downward to the water-table. The attainment of an anaerobic environment may result in the biologic production of contaminants such as hydrogen sulphide.

Certain types of bacteria and viruses, which are small enough to pass through the sediment pore spaces, may contaminate ground water. The survival of microorganisms in ground water is highly dependent upon the physical environment and the availability of nutrients. In general, most pathogenic bacteria do not travel more than a few hundred feet from their source.

Hydrologic Implications of Ground Water Pollution

The preceding discussion has demonstrated that the pollution of ground water and surface water is not completely analogous. However, ground waters do become polluted and the full impact is generally not appreciated due to an imperfect understanding of ground-water hydrology.

Ground water moves very slowly, usually at velocities between 5 feet per year and 5 feet per day. At these velocities water remains within most ground-water systems for long periods of time. Hence, if an aquifer becomes polluted an extended period of time is required before contaminated water is discharged from the system. Furthermore, the slow rates of ground-water movement result in laminar flow. Under laminar flow conditions lateral and vertical dispersion is minimized. Thus, dilution through mixing, which is a significant process for reducing the concentration of pollutants in surface waters, is severely restricted in ground water.

Ground water eventually discharges on the surface as springs, or into streams, lakes or the ocean. In southern Ontario such discharge generally constitutes the major portion of streamflow during most of the year. It is evident, therefore, that the discharge of polluted ground water could seriously impair the quality of some rivers and streams. In addition, due to the slow rate of ground-water movement, renovation of streams polluted in this way could be a long-term process.

Once ground water has become polluted there is generally very little that can be accomplished toward

restoring the original ground-water quality. As the natural processes of renovation, dilution and discharge are very slow, it is imperative that emphasis be placed upon the prevention of ground-water pollution.

SPRAY IRRIGATION

INTRODUCTION

Rather than presenting a cursory review of the entire field of waste disposal on land, spray irrigation has been selected for more detailed examination. This waste treatment method illustrates many of the principles previously discussed, and permits elucidation of the criteria essential for the maintenance of ground-water quality.

Spray irrigation, which has been rapidly gaining wider acceptance as a means for handling a variety of liquid wastes, is only one of several methods that employ the natural renovative capacity of soils and sediments. Other methods in common use are infiltration basins, and ridge and furrow spreading. Two types of spray irrigation are in common use: spray infiltration and spray runoff. Whether spray infiltration or runoff is employed depends upon the infiltration characteristics of the site.

Most spray irrigation systems presently in operation are handling municipal sewage effluents, or liquids from the food processing, dairy, and pulp and paper industries. These liquids, in terms of both quantity and quality, are not suitable for discharge to watercourses without pretreatment. Although the wastes from each of these sources are not identical in chemical composition, in general they are characterized by high oxygen demands and frequently contain plant nutrients.

The rationale for spray irrigation varies from operation to operation and from region to region. Many systems are established solely for upgrading the quality of the waste discharge. Other operations, particularly in areas where fresh water is a scarce commodity, are designed with the emphasis placed upon the benefits that may be realized in terms of increased crop yields, or upon renovation of the waste water to the extent that it may be reused. Frequently the water for reuse is obtained from wells which derive supplies from the aquifer that is recharged by the spray operation. The underlying "philosophy", be it biased toward either disposal or renovation, can be an important consideration since it may influence the selection of sites and design criteria of the operation both of which are significant determinants in the amount of ground-water pollution

that will result.

METHOD OF OPERATION

In spray infiltration operations, the waste is distributed over the site through a system of sprinklers. Since sprinklers are used, large particulate matter which could cause clogging must be removed prior to application. The distribution system is designed such that only a portion of the entire site receives waste at any given time. As a result, waste may be applied to various parts of the site on a rotation basis permitting a period of "rest" at each location between successive applications. The rate of application is regulated to prevent ponding or runoff which may result in objectionable odours. A reservoir is required to accumulate waste during non-growing and rainfall periods when application must be reduced or terminated. Except where spraying is carried out in forested areas, a cover crop that is capable of tolerating extremely moist conditions is maintained on the site. This crop improves the rate of infiltration, absorbs nutrients which are then removed during harvesting, and reduces the volume of liquid through transpiration. In total, therefore, the volume of sprayed liquid is assimilated by infiltration, evaporation and transpiration.

Spray runoff systems have been introduced in many areas where soils have low infiltration capacities. The waste is sprayed on a crop-covered slope, at a rate which greatly exceeds the infiltration capacity of the soil. As the waste water trickles down slope, aeration reduces the oxygen demand, the cover crop absorbs some of the nutrients, and other dissolved components may be biologically or chemically degraded, or adsorbed on the soil and organic material. The effluent at the base of the slope is generally discharged to a surface-water course.

HYDROLOGIC AND POLLUTION ASPECTS OF SPRAY IRRIGATION

PROCESSES OF RENOVATION

As this paper is primarily concerned with the effects of spray irrigation on ground-water quality, spray runoff systems in which there is minimal infiltration will not be dealt with in detail. Spray infiltration systems, however, are significant sources of ground-water recharge and may deleteriously alter ground-water quality.

Many spray infiltration systems are presently in operation, but only at a few sites is the quality of

the infiltrating water and local ground water monitored. The available monitoring data indicate that some constituents present in the effluents may be efficiently removed during infiltration. The effectiveness of removal of these components is largely dependent upon prevailing physical, chemical and biological conditions within the soil environment. A review of some of the data illustrates the variables which are important for achieving a high degree of renovation, and the hydrogeologic parameters which must be defined if proposed operations are to be reliably evaluated in terms of their ground-water pollution potential.

Table 1 (Sopper, 1971) shows the degree of renovation afforded sewage effluent by percolation through four feet of soil in forested areas of Pennsylvania. The degree of renovation is expressed as a percentage reduction in the average concentration of each constituent in the effluent. It can be seen that the degree of removal varies widely from component to component. Phosphate is almost totally removed through adsorption, incorporation into insoluble calcium, magnesium and iron salts and uptake by vegetation. Methylene blue active substance (MBAS) concentrations are reduced to a lesser extent by adsorption and biologic degradation. The relative effectiveness of MBAS adsorption has not been evaluated quantitatively, but Fink et al, (1970), indicate that the most adsorptive soils have high free iron oxide and clay contents, and low cation exchange capacities. Therefore, the effectiveness of adsorption in renovation is closely related to soil mineralogy.

Nitrate is removed less effectively than phosphate, and the degree of removal is dependent upon the physical and chemical characteristics of the soil. Nitrate is only weakly adsorbed and does not become incorporated into insoluble salts. Only through bacterial denitrification or uptake by vegetation is the nitrate concentration diminished. Unfortunately, denitrification requires anaerobic conditions which adversely affect BOD removals and cause odours. Also, vegetative assimilation is not necessarily complete. Sopper (1971), states that the degree of reduction of nitrate gradually diminished during 6 years of operation until at a depth of 4 feet initial concentrations were only reduced by 27-47 per cent. Concern was expressed that nitrate contamination of ground water could become a problem in the future.

Table 2 (Sopper, 1971) shows the concentrations of some constituents in percolate water samples collected from pan lysimeters located in a hardwood plot which received 4 inches of effluent per week during the period from April 15 to October 14, 1968. The concentrations of dissolved salts at various depths were increased or

Table 1. Average renovation of the sewage effluent by the forest floor and soil on the experimental plots during the irrigation period from April 9 to November 12, 1968.

Plot and soil depth	Weekly application	MBAS	NO_3-N	Cl	P
		Renovation (in percent)			
Hardwood	1				
F.F.		70.0	*	52.4	45.0
6 inches		71.7	*	69.6	99.9
24 inches		83.0	*	2.0	99.9
48 inches		78.0	70.6	*	99.9
Red Pine	1				
F.F.2/		71.2	*	29.7	19.5
6 inches		86.4	*	00.9	93.4
12 inches		86.4	*	18.3	96.9
24 inches		1/	*	22.6	97.0
48 inches		1/	47.1	*	98.9
Red Pine	2				
F.F.		71.2	*	28.7	23.1
6 inches		74.6	*	*	88.1
12 inches		1/	*	*	98.4
24 inches		1/	*	*	98.7
48 inches		81.4	*	*	99.5
Old Field	2				
6 inches		64.4	5.9	29.1	96.7
12 inches		1/	*	*	99.1
24 inches		1/	3.9	23.9	98.5
48 inches		72.9	27.5	33.4	99.4

1/ Insufficient sample volume for complete chemical analyses.

2/ Forest floor (1.5 to 2.0 inches thick).

* No renovation.

Table 2. Average concentration of constituents in the percolate water samples collected from pan lysimeters located in the hardwood plot which received 4 inches of effluent per week during the period April 15 to October 14, 1968.

	Cl	Na	K	Ca	Mg	Mn	B
			Concentration in mg/liter				
Effluent Quality	46.4	40.2	18.6	26.4	13.3	0.12	0.37
Soil Depth-inches							
6	46.3	41.0	13.7	26.1	13.4	0.09	0.29
12	55.6	39.5	12.9	18.3	12.6	0.07	0.27
24	66.9	54.6	6.6	10.6	6.8	0.34	0.27
36	77.3	53.2	5.3	9.5	9.5	0.36	0.28
48	53.1	54.9	3.2	7.1	6.2	0.04	0.12

decreased in variable amounts. Increased concentrations for ions such as chloride are due to evaporation and transpiration of a portion of the effluent during infiltration. Chloride concentrations are not reduced as the effluent percolates because this ion does not participate to any extent in biologic, adsorptive or exchange reactions. The concentration of chloride in this percolate was not sufficiently high to cause problems in ground water; however, if wastes have high concentrations of ions such as chloride, percolation through the soil will not remove these components and ground and surface water pollution could result.

Sopper's results for the Pennsylvania study do not contain data for the removal of BOD, pathogenic organisms or trace elements. In general, BOD reductions in spray irrigation operations exceed 90 per cent. An important criteria for effective removal of an oxygen demand is the maintenance of an aerobic environment in the soil. Pathogenic bacteria and viruses are a potential problem only in operations employing sewage effluents. Unfortunately, little is known regarding the viability of these organisms in the ground-water environment. Limited experience indicates that bacteria generally do not travel more than a few hundred feet from their source. Only a small amount of research has been conducted to determine the efficiency with which soils remove trace elements, particularly metals. Lehman and Wilson (1971) present data which indicate that soils may become saturated with respect to several trace metals in less than three years. The most favourable trace metal fixation results were obtained with intermittent irrigation treatments. The maintenance of an aerobic environment appears essential for reducing trace metal translocation.

The preceding discussion has demonstrated that the processes of waste renovation by spray infiltration are complex and varied and that many factors related to the composition of the waste, the physical and chemical environment within the soil, and the design of the spray operation are important in determining the degree of renovation achieved. Depending upon the composition of the waste a number of processes may affect renovation. If biologic degradation or assimilation is required to remove oxygen demands and nutrients, an aerobic environment must be maintained within the soil that will permit the establishment of a permanent vigorous bacterial community and cover crop. An aerobic environment can be maintained by carefully regulating the spray rate and frequency to prevent a condition of fluid saturation from developing in the soil. The rate of application must also be low enough so that the effluent does not percolate downward too rapidly to be assimilated. Thus, for maximum renovation waste may have to be applied at a

rate which does not nearly approach the maximum infiltration capacity of the soil. High concentrations of constituents which are removed through adsorption or exchange may cause long-term problems if the soil horizon becomes saturated with respect to these components. The capacity for adsorption or exchange depends largely upon the mineralogy and grain size of the soil. In general, it would be expected that the coarser soils which permit more rapid infiltration would have lower capacities for adsorption and exchange. Wastes that have high concentrations of ions such as chloride, which is not removed during infiltration, may seriously contaminate ground waters. Evaporation and transpiration of a portion of the waste prior to percolation only serves to increase concentrations in the percolate and ground water. Additional problems may arise if effluents have high concentrations of sodium. Sodium exchanges with calcium and magnesium on clays causing swelling and a reduction in infiltration capacity.

HYDROLOGIC ASPECTS

Hydrologic conditions at the operation site are an important consideration. The amount of liquid waste applied greatly exceeds rainfall, and results in an increased addition of fluid to the ground-water system. In an unconfined aquifer situation the water-table will mound beneath the spray site. As the height of the mound increases the rate of ground-water flow away from the site becomes greater. When a stable mound configuration is established the increase in ground-water flow from the site balances the new input of effluent. The development of a ground-water mound will alter natural water-table gradients, and may cause some of the waste to flow in different directions than the normal direction of ground-water flow. If the natural gradient is very low, the flow of waste may be nearly radial from the site.

Where the water-table is shallow, even if only seasonally, the mound developed beneath a spray site may approach the surface. In this instance the soil could become saturated with fluid. Saturated conditions significantly reduce the capacity of the soil for renovation. Similar problems may also arise where the normal water-table surface is deep, if relatively impermeable strata are present near the surface. Under these conditions a shallow perched water-table situation may develop. Thus, it can be seen that there are specific geologic and hydrologic conditions that are necessary for the safe operation of any system.

BACKGROUND INFORMATION REQUIRED FOR EVALUATION OF PROPOSED SITES

Considering the large number of factors that are important in a spray-infiltration operation it is evident that detailed studies are required to determine the pollution potential. Proper and complete hydrogeologic, soil, and design data can permit prior recognition of areas susceptible to ground- and surface-water pollution, and provide a reasonable assurance that an investment in a spray operation will be protected. The type of background information that is felt necessary for an adequate evaluation of proposed sites is listed below:

(1) The quantity of waste to be disposed and a detailed chemical analysis of the waste.

(2) Design criteria of the spray system - i.e. rate and frequency of application, type of cover crop, frequency of harvesting.

(3) Ground surface topography.

(4) A soil study defining the type, texture, thickness, sorptive and exchange capacity, permeability, and percolation characteristics.

(5) The subsurface stratigraphy at the proposed site as determined from boreholes.

(6) The lateral continuity and permeability of the stratigraphic units.

(7) The depth and elevation of the water-table or piezometric surface for each aquifer.

(8) The direction of ground-water flow in each aquifer.

(9) The distance to nearby wells and watercourses.

(10) The total depth, static water elevation, and use of nearby wells.

(11) The quality of the water from test holes, nearby wells, and surface water courses including chloride, sulphate, iron, hardness, alkalinity, pH, nutrient cycle, BOD, COD, and bacteria.

A comprehensive program should be placed in operation to monitor ground-water and surface-water quality. Boreholes utilized for ground-water sampling should be constructed in such a manner that they can be pumped to obtain representative samples.

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